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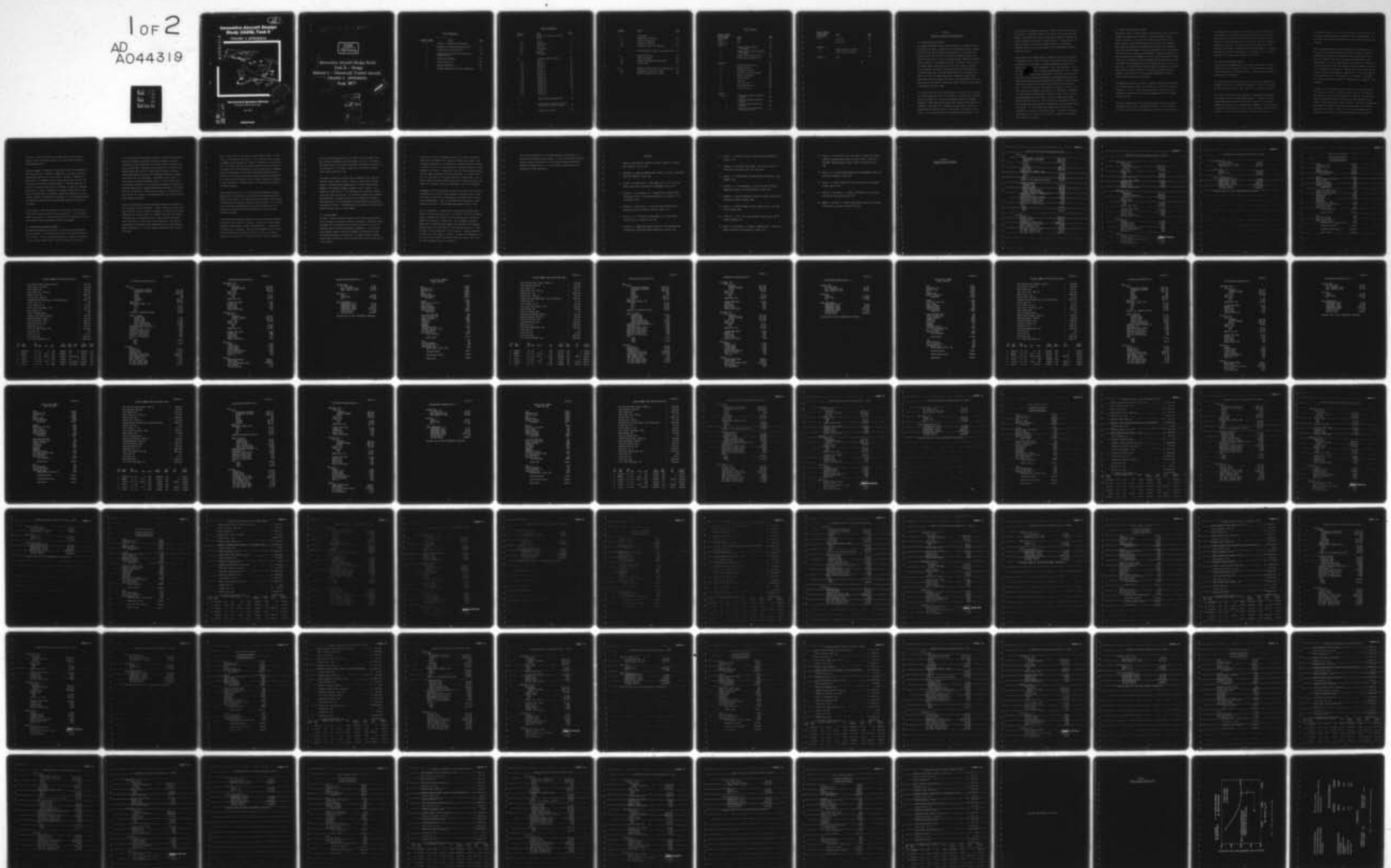
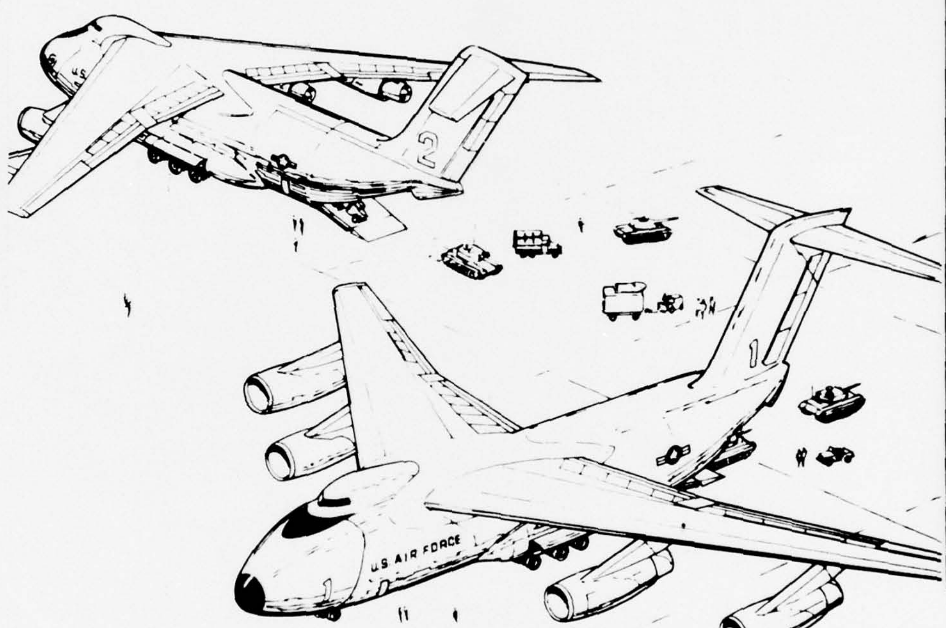


Innovative Aircraft Design Study (IADS), Task II

VOLUME II APPENDICES



Aeronautical Systems Division

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Innovative Aircraft Design Study

Task II – Design

Subtask I – Chemically Fueled Aircraft

VOLUME II. APPENDICES

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APPENDIX A

ANALYSIS OF INNOVATIVE CONFIGURATIONS

1.0 CANARD CONFIGURATION CONCEPT

The canard configuration concept has been extensively studied and applied to a number of aircraft. Applications to large subsonic cargo or transport aircraft are few, where the basic configuration has a high aspect ratio wing and the tail arm is large. An efficient transport requires a high cruise lift-drag ratio, in order to minimize the fuel burned, which results in the selection of a high aspect ratio wing. Additional cruise drag due to trimming results from the choice of an aft tail, canard, or elevons. In this situation, the wing is the most efficient lifting element due to its higher aspect ratio, thus the transport aircraft is relatively less sensitive to the trim concept selected, as compared to combat aircraft types which utilize low aspect ratio wings. Other requirements for transports include a good high-lift system and loading flexibility, which requires a large center of gravity range.

As relatively large tail arms are available for transport aircraft, the use of a canard rather than a tail will not result in a significantly improved cruise lift-drag ratio. The canard configuration obtains a low-speed advantage in that trimming the airplane with a upward lift can result in an increase in flaps-down lift. Trimming may be restricted to lower flap angles because of required margins on the maximum lift capability of the canard. Thus, body angles of attack during approach may be higher. High

lift devices may be needed on the canard. Reliability and fail-safe systems are essential. Directional instability can result from vortices shed from canards. The effect of the canard vortices can be altered by planform and location changes which require wind tunnel testing. For these reasons, the canard, as applied to a military transport aircraft, is regarded as a relatively high risk at this time, pending further development to resolve these major points.

Studies dealing with canards applied to commercial aircraft are discussed in References 1 and 2. Use of the canard in these applications emphasized the potential for improvements in landing performance and reductions in approach noise. Only small improvements, if any, were predicted in cruise lift-drag r[illegible] Reference 3 discusses the SAAB Viggen 37, which is frequently cite[illegible] successful canard application. The results of wind tunnel and flight testing regarding the favorable interference achieved with this close-coupled canard and wing configuration are discussed. Note that these results were achieved for low aspect ratio planforms of the canard and wing. The size and location of the canard with respect to the wing is also fairly unique for achievement of favorable lift interference. References 4, 5 and 6 discuss the application of canards to combat aircraft and show lift-drag comparisons with aft tails. One set of study results shows higher lift-drag ratios at $M = .85$ for an aft tail configuration relative to the canard case, when comparable single vertical tail configuration data are examined. It is thus evident that application of canards must be considered on an individual configuration basis. Significant performance improvements due to application of a canard to a large military transport do not appear very probable.

2.0 TANDEM WING CONFIGURATION CONCEPT

Exploratory studies on concepts leading to possible reductions in drag have included the tandem wing configuration. Possible advantages include: reduced wing weight -- since two smaller wings should be lighter than a single large one, reduced parasite drag due to elimination of empennage, and further drag reduction by laminarization of shorter chord surfaces at lower cruise Reynolds numbers. Possible disadvantages of this configuration include; difficulty in locating the powerplants, increased drag-due-to-lift due to lifting system interference, difficulty of providing takeoff rotation capability, and inherent structural advantages may be eliminated due to the high inertia loads (produced by the crash load design criteria on the high rear wing). Initial preliminary weight estimates indicated that an improvement in the empty weight fraction in the order of 10 percent might be possible. Based upon this, further work was accomplished in order to evaluate this configuration in more detail.

The concept was applied to a commercial transport, meeting the requirements for intermediate range capability, and these basic studies are discussed in References 7, 8 and 9. These results are relevant to the military cargo transport configuration as the volume requirements and overall efficiency goals are similar.

Results of configurations, structures and aerodynamic studies, including a low speed wind tunnel test, indicated the following: (a) a satisfactory solution to the balance problem appears very difficult with the location of

the engines and wing on the rear of the fuselage, (b) weight benefits due to the advantages in the configuration were offset because of the weight penalty due to the high rear wing inertial loads (as required for crash protection), and the drag-due-to-lift is 30 percent worse than a comparable monoplane configuration. Wind tunnel test results confirmed the higher drag-due-to-lift values, as predicted by theory of Reference 10, for example. Based upon these findings, the tandem wing configuration is not a suitable candidate for a military cargo transport at this time.

3.0 TAIL-LESS CONFIGURATION CONCEPT

The configuration considered here is one in which the payload is entirely carried within a body and not in the wing. The distributed load concept, in which the payload is carried in the wing, is being studied separately by Boeing and other contractors.

This configuration most likely would have a wing with some sweepback and a thickness ratio similar to current jet transports. Elevons would probably be used for control and trim. Small vertical tails may also be required.

The tail-less configuration has traditionally been assessed and examined with respect to its obvious performance potential. The pure flying wing concept was based upon maximizing the ratio of maximum lift to minimum parasite drag when compared to conventional arrangements. This same figure-of-merit may also be applied to the tail-less configuration under consideration here. In this case, a thinner wing is used as the payload is in a

conventional fuselage. The ratio of minimum parasite drag coefficient for all wings airplanes compared to conventional types is approximately 1:2. For the tail-less concept considered here, the ratio would be slightly less favorable.

The low speed performance is restricted because of the limited ability to trim out the large pitching moments which occur with high lift devices. Depending upon the takeoff and landing performance required, this could result in a penalty if the wing is not sized for predominately cruise considerations. Values of trimmed maximum lift coefficient in the order of 1.7, have been noted in published reports, which is considerably less than 3.0 for conventional configurations. Because the elevons are used for trim as well as control, the trimmed c.g. range is only 5 or 6 percent compared with conventional values in the order of 12 or 14 percent. This narrow c.g. range reduces desired versatility in loading which is needed for cargo transports.

In general, a well-developed automatic flight control system is necessary for this type of aircraft. All-wing aircraft have a very low cross-wind derivative; thus a low side force results from side-slip. Some cross-wind force is required for precision flight such as tight formation flying or landing. Dynamic longitudinal response to gusts is such that the disturbance may perturb the aircraft further from the trim attitude, thus requiring more active pilot control. Dutch roll is more critical because of the combination of relatively large effective dihedral and low weathercock

stability. Spinning and tumbling characteristics would also have to be studied in detail for specific designs. Spin was a problem on some all-wing prototype aircraft.

There are a number of references available pertaining to the development of this type of aircraft. Northrop, in Reference 11, discusses in depth the problems associated with tail-less aircraft. Askensas, in Reference 12, shows results of a parametric study in which wing thickness ratios of over 12 percent are predicted for best performance. A wing thickness ratio of less than 12 percent thickness ratio is predicted as optimum for wing-body configurations. Lange, in Reference 13, discusses a swept-wing tail-less design in a recent paper, and forecasts reduced fuel consumption for such a concept. However, he concludes that realization of its performance potential will depend upon the extent to which development programs are applied to this design.

For the reason of low trimmed maximum lift coefficients, and stability and flight control questions, the tail-less configuration -- with the payload carried in the body -- is considered unsuitable for application to a military cargo transport without considerable technical development.

4.0 OBLIQUE WING CONFIGURATION CONCEPT

The oblique wing concept, as applied to a large military cargo transport, has been reviewed. The findings relative to this configuration application are as follows. With aft fuselage mounted engines, loadability and center of gravity travel problems result. Placing the engines on the wing to

solve the balance problem produces aerodynamic interference and mechanical reliability problems, as an engine swiveling arrangement is required. Tailored pylon wing intersections for individual nacelle locations would have to be developed. Aerodynamic coupling between the longitudinal and lateral motions exist which will require modified control techniques. A slight weight penalty, relative to the reference configuration, probably exists due to the pivot arrangement. Considerable mission flexibility exists due to the variable wing sweep feature. Cruise lift-drag ratios will be about the same as for the reference configurations at comparible structural aspect ratios. Because these problems represent a high development risk, and there is a slight performance panelty in carrying out the basic mission, this concept is considered unsuitable for the large military cargo transport application.

Studies on the oblique wing concept have been conducted for transonic as well as subsonic cruise applications. Transonic commercial transports have been configured using this concept for pruposes of eliminating sonic booms associated with overland flights with attendent significant time savings. Kulfan and Jones, in References 14 and 15, show comparisons with other fixed delta wing and variable swept wing configurations. Application of this concept to the subsonic cruise speed regime has also been studied by Lange in Reference 16. A military transport configuration was included in this study.

While it seems clear that the oblique wing can generate higher lift-drag ratios in the transonic speed range, it is not clear that such an unusual arrangement could be successfully adapted to a complete aircraft configuration. The oblique wing aircraft concept introduces some new problems and considerable effort has been devoted to finding a good general arrangement. Engine and landing gear locations pose configuration problems which are difficult to solve because of balance or drag interference considerations. Also, factors such as increased structural weight, aeroeleastic instability, or other configurational features tend to nullify the purely aerodynamic efficiency advantage.

Boeing study results for a M = 1.2 oblique wing 200 passenger transport showed that this configuration had the lowest gross weight required for a 3000 mile range mission. The fixed delta wing configuration required about 10 percent more gross weight to accomplish the same mission. The lift-drag ratio of the delta configuration was significantly lower than for the oblique wing configuration, which offset the higher structural weight efficiency advantage.

The oblique wing configuration adopted for these studies featured engines installed on the aft portion of the body. A balance and loading analysis indicated a center-of-gravity range of 25 percent M.A.C. Forward allast was required for low payloads. Selective fuel management with an aft body fuel tank allowed the minimization of cruise trim drag. The slightly higher structural weight of the oblique wing was not primarily associated

with the variable geometry feature, but rather it was the result of the basic strength requirements of the high aspect ratio wing. The effect of the higher aspect ratio produces an advantage in aerodynamic efficiency, as the drag-due-to-lift is reduced. Another major performance difference results due to reduced wave drag.

The subsonic oblique wing transport study of Reference 3 built upon the previously cited transonic studies. There is a significant size effect, however, in the requirements established for a military transport when compared to the domestic passenger transport initially studied. Gross weights are in the order of 1.3 million pounds and six engines, of 60,000 pound thrust each, are required. The size effect produces major configuration problems for a transport aircraft from the standpoints of balance, when the payload is a high percentage of the gross weight and the engines are mounted on the wing. These problems were also noted on the much smaller transonic aircraft, but to a lesser degree.

5.0 RAM WING CONCEPT

Ram wing is a general term which stands for any lifting surface operating in the proximity to the ground or other solid boundary. Theoretical studies have shown that the induced drag of a planar wing flying at a given lift decreases steadily to zero as the ground is approached. To utilize this drag advantage, however, requires an extremely low altitude cruise mode. This perhaps precludes its operation as an all weather system. Despite obvious practical problems, interest has been shown in maritime applications of this concept.

Indications are, that for overwater operation, the lifting surfaces will need to be of low aspect ratio in order to withstand wave; impact, thus increasing induced drag. On the other hand, the water surface will behave in a manner similar to a solid ground plane in tending to reduce this drag component. In practice, it appears most likely the minimum operating height will be limited by the need to minimize wave impact. As a result, there will be a lower bound to the possible reduction of induced drag. Also, in order to obtain sufficient clearance over water for rough sea states a very large size is required, which is a disadvantage of the ram wing concept.

Advantages of the ram wing concept are that high values of lift-drag ratio are possible as a result of flight operation in the ground effect. When end-plated, an aspect ratio 2.0 wing may have lift-drag ratios of from 20 to 40 in ground effect. Use of a low aspect ratio wing results in high structural efficiency, so the estimated empty weight fraction is low.

Ashill, in Reference 17, extends planar wing induced drag ground effect theory to the end-plated case, which is of interest for the ram wing design. Lange, in Reference 18, discusses a ram wing design, which utilizes the benefits of reductions in induced drag. The wing geometry selected is Aspect Ratio 2, sweep angle zero degrees, and thickness ratio 15 percent. The wing span for this configuration is 245 feet and cruise is at 12 feet altitude. The gross weight was 1.2 million pounds. Turboprop power was utilized for a cruise speed of 110 knots. The additional References 19 and 20 discuss topics related to the ground effect wing concept, and utilize the theory developed by Ashill in Reference 17.

The ram wing configuration is considered unsuitable for application to a military cargo transport design, because: (a) the cruise altitude constraint severely restricts the versatility, (b) the overall design would require extensive development period, (c) size constraints preclude selection of anything but a very large vehicle.

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APPENDIX B

PARAMETRIC DESIGN SUMMARIES

****CONFIGURATION CHARACTERISTICS ****

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	7133.333
AERODYNAMIC REFERENCE	7133.333
WETTED	12346.597
GLOVE	.000
YAHUDI	.000
AILERONS	300.880
SPOILERS	329.325
SPAN, FEET	238.886
TRAPEZOIDAL CHORDS, FEET	
ROOT	43.005
S.O.B.	40.222
TIP	16.716
MGC	31.782
CHORD OF THE CONSTANT SECTION	40.376
SWEEPS, DEGREES	
LEADING EDGE	10.000
QUARTER CHORD	6.917
TRAILING EDGE	-2.508
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	8.000
AERO REF. ASPECT RATIO	8.000
TRAPEZOIDAL TAPER RATIO	.389
AERO REF. TAPER RATIO	.4156
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	422123
BODY	0
TOTAL	422123
FUSELAGE - - -	
LENGTH, FT.	281.670
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	20204.681
AERODYNAMIC WETTED AREA	19126.131
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	11.136
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEPANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

****CONFIGURATION CHARACTERISTICS - 1****

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	1644.348
EXPOSED PLANFORM	1404.194
WETTED	2843.890
SPAN, FEET	77.206
CHORD, FEET	
ROOT	30.673
TIP	11.922
MOMENT ARM, FEET	130.977
LEADING EDGE SWEEP	10.000
AVERAGE T/C	.0920
TAPER RATIO	.389
ASPECT RATIO	3.625
VOLUME COEFFICIENT	.950
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	868.637
EXPOSED PLANFORM	868.637
WETTED	1763.560
HEIGHT, FEET	37.651
CHORD, FEET	
ROOT	33.226
TIP	12.915
MOMENT ARM, FEET	129.005
LEADING EDGE SWEEP	10.000
AVERAGE T/C	.1000
TAPER RATIO	.389
ASPECT RATIO	1.632
VOLUME COEFFICIENT	.066
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	[redacted] STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	1.824
SFC CONSERVATISM	1.050

****CONFIGURATION CHARACTERISTICS - 2****

LANDING GEAR - - -	
NO. MAIN TIRES	24.000
MAIN,TRUNION TO AXLE	136.075
NOSE,TRUNION TO AXLE	136.075
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	1749.887
L/D	5.000
CARGO COMPARTMENT- - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	208.333
COMPARTMENT VOLUME	53333.333
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	400000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

GROUP WEIGHT SUMMARY

****
* MODEL 1044.000 *
****

WING	119995
HORIZONTAL TAIL	13502
VERTICAL TAIL	6254
BODY	137548
LANDING GEAR	55864
NACELLE STRUCTURE	10623
STRUCTURE	317658
ENGINE	38359
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	2725
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	8947
PROPULSION	51021
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	10328
HYDRAULICS	5465
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	7532
AIR COND. AND ANTI-ICING	5036
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	39191
WEIGHT EMPTY	407870
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	411
UNAVAILABEL FUEL	844
NONEXPENDABLE USEFUL LOAD	2895
OPERATING WEIGHT	410766
MISSION GROSS WEIGHT	1070000
AMPR WEIGHT	343439

DESIGN #1

MISSION SUMMARY DATA FOR MISSION FERRY 1

Ferry Mission Gross Weight, 1000 Lbs.	=	1070.000
Ferry Payload, 1000 Lbs.	=	400.000
Ferry Range, N.M.	=	3566.945
Total Ferry Fuel, 1000 Lbs.	=	259.234
Reserve Fuel, Lbs.	=	24984.102
Mission Fuel, 1000 Lbs.	=	234.250
Average Mission Range Factor, Taxi-Climb-Cruise	=	14436.128
Loiter Time, Hrs.	=	7.808
Loiter Radius, N. Mi.	=	127.028
Zero Loiter Time Radius, N Mi.	=	1783.473
Wing Loading, PSF	=	150.000
Thrust To Weight Ratio	=	.226
Takeoff Gross Weight, 1000 Lbs.	=	1070.000
Operating Weight, 1000 Lbs.	=	410.766
Take Off Distance, Feet	=	8060.767
Landing Distance, Feet	=	4092.729
Wing Area, Sq. Ft.	=	7133.333
Cruise Out Range Factor, NM	=	15150.406
Cruise Out SFC	=	.617
Cruise Out L/D	=	22.174
Cruise Out Drag	=	47298.230
C.O. Thrust Available, Lbs.	=	66477.703

LEG. NO.	LEG NAME	CON-FIG	PWR	DIST	TIME	INT. WEIGHT	INT. MACH	INT. ALT	FINAL WEIGHT	FINAL MACH
1.	Takeoff 3	1.0	6.0	.0	.052	1070000	.000	.0	1066720	.000
2.	MAXRCL	1.0	5.0	127.0	.326	1066720	.471	.0	1048777	.746
3.	Cruise 3	1.0	6.0	3439.9	7.569	1048777	.786	32203.4	835750	.786
4.	Loiter	1.0	6.0	.0	.500	835750	.312	.0	823727	.312
5.	Cruise 2	1.0	6.0	127.0	.284	842843	.780	35896.4	835750	.780
6.	Loiter	1.0	6.0	.0	7.808	1048777	.739	32197.6	842843	.684

DESIGN #2

CONFIGURATION CHARACTERISTICS

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	8791.946
AERODYNAMIC REFERENCE	8791.946
WETTED	15465.358
GLOVE	.000
YAHUDY	.000
AILERONS	377.410
SPOILERS	400.345
SPAN, FEET	265.209
TRAPEZOIDAL CHORDS, FEET	
ROOT	47.886
S.O.B.	45.076
TIP	18.416
MGC	35.325
CHORD OF THE CONSTANT SECTION	44.939
SWEEPS, DEGREES	
LEADING EDGE	11.000
QUARTER CHORD	7.904
TRAILING EDGE	-1.598
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	8.000
AERO REF. ASPECT RATIO	8.000
TRAPEZOIDAL TAPER RATIO	.385
AERO REF. TAPER RATIO	.4086
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	578698
BODY	0
TOTAL	578698
FUSELAGE - - -	
LENGTH, FT.	281.670
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	20204.681
AERODYNAMIC WETTED AREA	18943.951
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	11.136
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEP ANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

DESIGN #2

CONFIGURATION CHARACTERISTICS

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	2076.593
EXPOSED PLANFORM	1772.826
WETTED	3590.579
SPAN, FEET	86.764
CHORD, FEET	
ROOT	34.572
TIP	13.295
MOMENT ARM, FEET	130.977
LEADING EDGE SWEEP	11.000
AVERAGE T/C	.0920
TAPER RATIO	.385
ASPECT RATIO	3.625
VOLUME COEFFICIENT	.876
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	1178.136
EXPOSED PLANFORM	1178.136
WETTED	2391.831
HEIGHT, FEET	43.849
CHORD, FEET	
ROOT	38.811
TIP	14.925
MOMENT ARM, FEET	129.005
LEADING EDGE SWEEP	11.000
AVERAGE T/C	.1000
TAPER RATIO	.385
ASPECT RATIO	1.632
VOLUME COEFFICIENT	.065
NACELLES - - -	
NUMBER	4.000
FITNESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	2.213
SFC CONSERVATISM	1.050

CONFIGURATION CHARACTERISTICS - 2

LANDING GEAR - - -	
NO. MAIN TIRES	24.000
MAIN, TRUNION TO AXLE	134.850
NOSE, TRUNION TO AXLE	134.850
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	1983.810
L/D	5.000
CARGO COMPARTMENT - - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	208.333
COMPARTMENT VOLUME	53333.333
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	400000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

DESIGN #2

GROUP WEIGHT SUMMARY
MODEL 1044.000

WING	149024
HORIZONTAL TAIL	17654
VERTICAL TAIL	9201
BODY	144165
LANDING GEAR	66097
NACELLE STRUCTURE	12771
STRUCTURE	368595
ENGINE	48854
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	3668
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	10857
PROPULSION	64369
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP	960
SURFACE CONTROLS	12063
HYDRAULICS	6803
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	7578
AIR COND. AND ANTI-ICING	5052
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	42326
WEIGHT EMPTY	475290
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	499
UNAVAILABEL FUEL	1157
NONEXPENDABLE USEFUL LOAD	3296
OPERATING WEIGHT	478587
MISSION GROSS WEIGHT	1310000
AMPR WEIGHT	396520

MISSION SUMMARY DATA FOR MISSION FERRY 1

Ferry Mission Gross Weight, 1000 Lbs.	=	1310.000
Ferry Payload, 1000 Lbs.	=	400.000
Ferry Range, N.M.	=	5470.752
Total Ferry Fuel, 1000 Lbs.	=	431.413
Reserve Fuel, Lbs.	=	34691.727
Mission Fuel, 1000 Lbs.	=	396.722
Average Mission Range Factor, Taxi-Climb-Cruise	=	15165.283
Loiter Time, Hrs.	=	12.327
Loiter Radius, N. Mi.	=	119.485
Zero Loiter Time Radius, N. Mi.	=	2735.376
Wing Loading, PSF	=	149.000
Thrust To Weight Ratio	=	.224
Takeoff Gross Weight, 1000 Lbs.	=	1310.000
Operating Weight, 1000 Lbs.	=	478.587
Take Off Distance, Feet	=	8091.891
Landing Distance, Feet	=	3948.629
Wing Area, Sq. Ft.	=	8791.946
Cruise Out Range Factor, NM	=	15652.047
Cruise Out Sec	=	.642
Cruise Out L/D	=	22.226
Cruise Out Drag	=	57834.639
C.D. Thrust Available, LBS.	=	57834.639

LEG NO.	LEG NAME	CON-FIG	PWR	DIST	TIME	INT. WEIGHT	INT. MACH	INT. ALT	FINAL WEIGHT
1.	Takeof 3	1.0	6.0	.0	.052	1310000	.000	.0	1306019
2.	MAXRCL	1.0	5.0	119.5	.302	1306019	.479	.0	1285534
3.	Cruise 3	1.0	6.0	5351.3	11.828	1285534	.785	31584.7	913278
4.	Loiter	1.0	6.0	.0	.500	913278	.267	.0	900157
5.	Cruise 2	1.0	6.0	119.5	.266	920397	.782	38150.8	913278
6.	Loiter	1.0	6.0	.0	12.327	1285534	.747	31477.0	920397

CONFIGURATION CHARACTERISTICS

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	10063.291
AERODYNAMIC REFERENCE	10063.291
WETTED	17863.598
GLOVE	.000
YAHUDI	.000
AILERONS	436.913
SPOILERS	454.176
SPAN, FEET	283.736
TRAPEZOIDAL CHORDS, FEET	
ROOT	51.539
S.O.B.	48.674
TIP	19.395
MGC	37.885
CHORD OF THE CONSTANT SECTION	48.325
SWEEPS, DEGREES	
LEADING EDGE	13.000
QUARTER CHORD	9.883
TRAILING EDGE	.243
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	8.000
AERO REF. ASPECT RATIO	8.000
TRAPEZOIDAL TAPER RATIO	.376
AERO REF. TAPER RATIO	.3985
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	711387
BODY	0
TOTAL	711387
FUSELAGE - - -	
LENGTH, FT.	281.670
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	20204.681
AERODYNAMIC WETTED AREA	18747.269
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	11.136
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEP ANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

CONFIGURATION CHARACTERISTICS - 1

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	2411.158
EXPOSED PLANFORM	2057.358
WETTED	4167.196
SPAN, FEET	93.493
CHORD, FEET	
ROOT	37.477
TIP	14.103
MOMENT ARM, FEET	130.977
LEADING EDGE SWEEP	13.000
AVERAGE T/C	.0920
TAPER RATIO	.376
ASPECT RATIO	3.625
VOLUME COEFFICIENT	.828
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	1417.766
EXPOSED PLANFORM	1417.766
WETTED	2878.158
HEIGHT, FEET	48.102
CHORD, FEET	
ROOT	42.831
TIP	16.118
MOMENT ARM, FEET	129.005
LEADING EDGE SWEEP	13.000
AVERAGE T/C	.1000
TAPER RATIO	.376
ASPECT RATIO	1.632
VOLUME COEFFICIENT	.064
NACELLES - - -	
NUMBER	4.000
FITNESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	2.662
SFC CONSERVATISM	1.050

CONFIGURATION CHARACTERISTICS - 2

LANDING GEAR - - -	
NO. MAIN TIRES	24.000
MAIN, TRUNION TO AXLE	134.592
NOSE, TRUNION TO AXLE	134.592
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	2236.960
L/D	5.000
CARGO COMPARTMENT - - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	208.333
COMPARTMENT VOLUME	53333.333
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	400000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

DESIGN #3

GROUP WEIGHT SUMMARY
MODEL 1044.000

WING	173508
HORIZONTAL TAIL	21065
VERTICAL TAIL	11488
BODY	150767
LANDING GEAR	77936
NACELLE STRUCTURE	15240
STRUCTURE	415803
ENGINE	61544
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	4683
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	13060
PROPULSION	80277
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	14008
HYDRAULICS	8389
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	7622
AIR COND. AND ANTI-ICING	5069
B.L.C. DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	45918
WEIGHT EMPTY	541999
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	600
UNAVAILABLE FUEL	1423
NONEXPENDABLE USEFUL LOAD	3663
OPERATING WEIGHT	545662
MISSION GROSS WEIGHT	1590000
AMPR WEIGHT	446123

DESIGN #3

MISSION SUMMARY DATA FOR MISSION FERRY 1

Ferry Mission Gross Weight, 1000 Lbs.	=	1590.000
Ferry Payload, 1000 Lbs.	=	400.000
Ferry Range, N.M.	=	7256.741
Total Ferry Fuel, 1000 Lbs.	=	644.338
Reserve Fuel, Lbs.	=	46816.056
Mission Fuel, 1000 Lbs.	=	597.522
Average Mission Range Factor, Taxi-Climb-Cruise	=	15397.782
Loiter Time, Hrs.	=	16.511
Loiter Radius, N. Mi.	=	114.243
Zero Loiter Time Radius, N Mi.	=	3628.371
Wing loading, PSF	=	158.000
Thrust To Weight Ratio	=	.222
Takeoff Gross Weight, 1000 Lbs.	=	1590.000
Operating Weight, 1000 Lbs.	=	545.662
Take Off Distance, Feet	=	8709.642
Landing Distance, Feet	=	3998.520
Wing Area, Sq. Ft.	=	10063.291
Cruise Out Range Factor, NM	=	15754.435
Cruise Out Sec	=	.621
Cruise Out L/C	=	23.571
Cruise Out Drag	=	66257.806
C. O. Thrust Available, Lbs.	=	100326.357

LEG NO.	LEG NAME	CON-FIG.	PWR	DIST	TIME	INT. WEIGHT	INT. MACH	INT. ALT	FINAL WEIGHT
1.	Takeof 3	1.0	6.0	.0	.052	1590000	.000	.0	1585212
2.	MAXRCL	1.0	5.0	114.2	.283	1585212	.491	.0	1561760
3.	Cruise 3	1.0	6.0	7142.5	15.561	1561760	.791	30582.2	992478
4.	Loiter	1.0	6.0	.0	.500	992478	.280	.0	977878
5.	Cruise 2	1.0	6.0	114.2	.252	999828	.790	40035.9	992478
6.	Loiter	1.0	6.0	.0	16.511	1561760	.750	30576.5	999828

DESIGN #4

COFIGURATION CHARACTERISTICS

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	10871.560
AERODYNAMIC REFERENCE	10871.560
WETTED	19856.943
GLOVE	.000
YAHUDI	.000
AILERONS	387.900
SPOILERS	398.583
SPAN, FEET	361.191
TRAPEZOIDAL CHORDS, FEET	
ROOT	44.705
S.O.B.	42.659
TIP	15.494
MGC	32.454
CHORD OF THE CONSTANT SECTION	41.784
SWEEPS, DEGREES	
LEADING EDGE	20.200
QUARTER CHORD	18.133
TRAILING EDGE	11.644
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	12.000
AERO REF. ASPECT RATIO	12.000
TRAPEZOIDAL TAPER RATIO	.347
AERO REF. TAPER RATIO	.3632
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	661710
BODY	0
TOTAL	661710
FUSELAGE - - -	
LENGTH, FT.	281.670
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	20204.681
AERODYNAMIC WETTED AREA	19018.743
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	11.136
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEP ANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

CONFIGURATION CHARACTERISTICS -

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	2462.454
EXPOSED PLANFORM	2115.312
WETTED	4287.263
SPAN, FEET	96.896
CHORD, FEET	
ROOT	37.745
TIP	13.082
MOMENT ARM, FEET	130.977
LEADING EDGE SWEEP	20.200
AVERAGE T/C	.0920
TAPER RATIO	.347
ASPECT RATIO	3.813
VOLUME COEFFICIENT	.914
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	1391.809
EXPOSED PLANFORM	1391.809
WETTED	2825.961
HEIGHT, FEET	52.070
CHORD, FEET	
ROOT	39.700
TIP	13.759
MOMENT ARM, FEET	129.005
LEADING EDGE SWEEP	20.200
AVERAGE T/C	.1000
TAPER RATIO	.347
ASPECT RATIO	1.948
VOLUME COEFFICIENT	.046
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	1.600
SFC CONSERVATISM	1.050

CONFIGURATION CHARACTERISTICS - 2

LANDING GEAR - - -	
NO. MAIN TIRES	24.000
MAIN, TRUNION TO AXLE	141.452
NOSE, TRUNION TO AXLE	141.452
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	1864.221
L/D	5.000
CARGO COMPARTMENT - - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	208.333
COMPARTMENT VOLUME	53333.333
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	400000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

DESIGN #4

GROUP WEIGHT SUMMARY
MODEL 1044.000

WING	261527
HORIZONTAL TAIL	22103
VERTICAL TAIL	12910
BODY	140848
LANDING GEAR	63725
NACELLE STRUCTURE	9382
STRUCTURE	471697
ENGINE	32562
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	2492
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	7848
PROPULSION	43893
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	11844
HYDRAULICS	6103
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	7555
AIR COND. AND ANTI-ICING	5026
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	41359
WEIGHT EMPTY	556949
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	361
UNAVAILABLE FUEL	1323
NONEXPENDABLE USEFUL LOAD	3324
OPERATING WEIGHT	560273
MISSION GROSS WEIGHT	1185000
AMPR WEIGHT	495711

DESIGN #4

MISSION SUMMARY DATA FOR MISSION FERRY 1

Ferry Mission Gross Weight, 1000 Lbs.	=	1185.000
Ferry Payload, 1000 Lbs.	=	400.000
Ferry Range, N.M.	=	3581.250
Total Ferry Fuel, 1000 Lbs.	=	224.727
Reserve Fuel, Lbs.	=	21190.856
Mission Fuel, 1000 Lbs.	=	203.536
Average Mission Range Factor, Taxi-Climb-Cruise	=	19003.390
Loiter Time, Hrs.	=	7.533
Loiter Radius, N. Mi.	=	211.712
Zero Loiter Time Radius, N Mi.	=	1790.625
Wing Loading, PSF	=	109.000
Thrust To Weight Ratio	=	.179
Takeoff Gross Weight, 1000 Lbs.	=	1185.000
Operating Weight, 1000 Lbs.	=	560.273
Take Off Distance, Feet	=	8020.471
Landing Distance, Feet	=	3378.100
Wing Area, Sq. Ft.	=	10871.560
Cruise Out Range Factor, NM	=	20527.285
Cruise Out SFC	=	.611
Cruise Out L/D	=	29.717
Cruise Out Drag	=	38918.114
C.O. Thrust Available, LBS	=	47935.982

LEG NO.	LEG NAME	CON-FIG.	PWR	DIST	TIME	INT. WEIGHT	INT. MACH	INT. ALT	FINAL WEIGHT
1.	Takeoff 3	1.0	6.0	.0	.052	1185000	.000	.0	1182123
2.	MAXRCL	1.0	5.0	211.7	.590	1182123	.416	.0	1156547
3.	Cruise 3	1.0	6.0	3369.5	7.463	1156547	.787	37798.6	981464
4.	Loiter	1.0	6.0	.0	.500	981464	.280	.0	971509
5.	Cruise 2	1.0	6.0	211.7	.480	991989	.769	37363.6	981464
6.	Loiter	1.0	6.0	.0	7.533	1156547	.737	37787.7	991989

CONFIGURATION CHARACTERISTICS

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	13302.752
AERODYNAMIC REFERENCE	13302.752
WETTED	24549.731
GLOVE	.000
YAHUDI	.000
AILERONS	482.761
SPOILERS	481.274
SPAN, FEET	399.541
TRAPEZOIDAL CHORDS, FEET	
ROOT	49.803
S.O.B.	47.713
TIP	16.787
MGC	36.014
CHORD OF THE CONSTANT SECTION	46.501
SWEEPS, DEGREES	
LEADING EDGE	22.500
QUARTER CHORD	20.451
TRAILING EDGE	13.973
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	12.000
AERO REF. ASPECT RATIO	12.000
TRAPEZOIDAL TAPER RATIO	.337
AERO REF. TAPER RATIO	.3518
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	899989
BODY	0
TOTAL	899989
FUSELAGE - - -	
LENGTH FT.	281.670
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	2024.681
AERODYNAMIC WETTED AREA	18817.359
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	11.136
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEP ANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

CONFIGURATION CHARACTERISTICS - 1

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	3058.596
EXPOSED PLANFORM	2626.091
WETTED	5324.100
SPAN, FEET	107.990
CHORD, FEET	
ROOT	42.366
TIP	14.280
MOMENT ARM, FEET	130.977
LEADING EDGE SWEEP	22.500
AVERAGE T/C	.0920
TAPER RATIO	.337
ASPECT RATIO	3.813
VOLUME COEFFICIENT	.836
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	1864.200
EXPOSED PLANFORM	1864.200
WETTED	3785.743
HEIGHT, FEET	60.262
CHORD, FEET	
ROOT	46.273
TIP	15.597
MOMENT ARM, FEET	129.005
LEADING EDGE SWEEP	22.500
AVERAGE T/C	.1000
TAPER RATIO	.337
ASPECT RATIO	1.948
VOLUME COEFFICIENT	.045
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	1.957
SFC CONSERVATISM	1.050

DESIGN #5

CONFIGURATION CHARACTERISTICS - 2

LANDING GEAR - - -	
NO. MAIN TIRES	24.000
MAIN,TRUNION TO AXLE	140.828
NOSE,TRUNION TO AXLE	140.828
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	2112.711
L/D	5.000
CARGO COMPARTMENT - - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	208.333
COMPARTMENT VOLUME	53333.333
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	400000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

DESIGN #5

GROUP WEIGHT SUMMARY
MODEL 1044.000

WING	332589
HORIZONTAL TAIL	28784
VERTICAL TAIL	18631
BODY	147605
LANDING GEAR	75938
NACELLE STRUCTURE	11362
STRUCTURE	568177
ENGINE	41906
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	3366
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	9603
PROPULSION	55865
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	13899
HYDRAULICS	7593
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	7601
AIR COND. AND ANTI-ICING	5042
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	44965
WEIGHT EMPTY	669006
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	441
UNAVAILABLE FUEL	1800
NONEXPENDABLE USEFUL LOAD	3881
OPERATING WEIGHT	672888
MISSION GROSS WEIGHT	1450000
AMPR WEIGHT	593932

MISSON SUMMARY DATA FOR MISSION FERRY 1

Ferry Mission Gross Weight, 1000 Lbs.	=	1450.000
Ferry Payload, 1000 Lbs.	=	400.000
Ferry Range, N.M.	=	5485.015
Total Ferry Fuel, 1000 Lbs	=	377.112
Reserve Fuel, Lbs.	=	30077.399
Mission Fuel, 1000 Lbs	=	347.035
Average Mission Range Factor, Taxi-Climb-Cruise	=	20050.395
Loiter Time, Hrs.	=	12.076
Loiter Radius, N. Mi.	=	210.843
Zero Loiter Time Radius, N Mi.	=	2742.508
Wing Loading, PSF	=	109.000
Thrust to Weight Ratio	=	.179
Takeoff Gross Weight, 1000 Lbs.	=	1450.000
Operating Weight, 1000 Lbs	=	672.888
Take Off Distance, Feet	=	8125.778
Landing Distance, Feet	=	3324.387
Wing Area, Sq. Ft.	=	13302.752
Cruise Out Range Factor, NM	=	21109.870
Cruise Out SFC	=	.614
Cruise Out L/D	=	30.574
Cruise Out Drag	=	46314.095
C.O. Thrust Available, Lbs	=	57576.662

LEG NO.	LEG NAME	CON-FIG	PWR	DIST	TIME	INT. WEIGHT	INT. MACH	INT. ALT	FINAL WEIGHT
L.	Takeof 3	1.0	6.0	.0	.052	1185000	.000	.0	1182123
2.	MAXRCL	1.0	5.0	210.8	.575	.446479	.425	.0	1416014
3.	Cruise 3	1.0	6.0	5274.2	11.552	1416014	.796	38136.4	1102965
4.	Loiter	1.0	6.0	.0	.500	1102965	.271	.0	1091743
5.	Cruise 2	1.0	6.0	210.8	.474	1114405	.776	39606.5	1102965
6.	Loiter	1.0	6.0	.0	12.076	1416014	.746	38127.3	1114405

****CONFIGURATION CHARACTERISTICS ****

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	14608.696
AERODYNAMIC REFERENCE	14608.696
WETTED	27080.734
GLOVE	.000
YAHUDI	.000
AILERONS	534.340
SPOILERS	525.270
SPAN, FEET	418.694
TRAPEZOIDAL CHORDS, FEET	
ROOT	52.393
S.O.B.	50.278
TIP	17.390
MGC	37.808
CHORD OF THE CONSTANT SECTION	48.892
SWEEPS, DEGREES	
LEADING EDGE	23.750
QUARTER CHORD	21.713
TRAILING EDGE	15.253
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	12.000
AERO REF. ASPECT RATIO	12.000
TRAPEZOIDAL TAPER RATIO	.332
AERO REF. TAPER RATIO	.3459
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	1038484
BODY	0
TOTAL	1038484
FUSELAGE - - -	
LENGTH, FT.	281.670
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	20204.681
AERODYNAMIC WETTED AREA	18657.542
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	11.136
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEPANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

****CONFIGURATION CHARACTERISTICS - 1****

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	3376.317
EXPOSED PLANFORM	2898.123
WETTED	5876.717
SPAN, FEET	113.460
CHORD, FEET	
ROOT	44.684
TIP	14.831
MOMENT ARM, FEET	130.977
LEADING EDGE SWEEP	23.750
AVERAGE T/C	.0920
TAPER RATIO	.332
ASPECT RATIO	3.813
VOLUME COEFFICIENT	.801
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	2107.274
EXPOSED PLANFORM	2107.274
WETTED	4279.856
HEIGHT, FEET	64.370
CHORD, FEET	
ROOT	49.388
TIP	16.392
MOMENT ARM, FEET	129.005
LEADING EDGE SWEEP	23.750
AVERAGE T/C	.1000
TAPER RATIO	.332
ASPECT RATIO	1.948
VOLUME COEFFICIENT	.044
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	[redacted] STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	2.255
SFC CONSERVATISM	1.050

****CONFIGURATION CHARACTERISTICS - 2****

LANDING GEAR - - -	
NO. MAIN TIRES	32.000
MAIN,TRUNION TO AXLE	126.989
NOSE,TRUNION TO AXLE	126.989
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	2314.641
L/D	5.000
CARGO COMPARTMENT- - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	208.333
COMPARTMENT VOLUME	53333.333
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	400000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

#

DESIGN #6

GROUP WEIGHT SUMMARY

****
* MODEL 1044.000 *
****

WING	372710
HORIZONTAL TAIL	32706
VERTICAL TAIL	21714
BODY	152709
LANDING GEAR	84950
NACELLE STRUCTURE	13004
STRUCTURE	626281
ENGINE	50022
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	4153
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	11064
PROPULSION	66230
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	15570
HYDRAULICS	8904
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	7635
AIR COND. AND ANTI-ICING	5054
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	47993
WEIGHT EMPTY	740503
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	508
UNAVAILABEL FUEL	2077
NONEXPENDABLE USEFUL LOAD	4225
OPERATING WEIGHT	744728
MISSION GROSS WEIGHT	1680000
AMPR WEIGHT	653946

MISSION SUMMARY DATA FOR MISSION FERRY1

FERRY MISSION GROSS WEIGHT, 1000 LBS.	=	1680.000
FERRY PAYLOAD, 1000 LBS	=	400.000
FERRY RANGE, N.M.	=	7178.545
TOTAL FERRY FUEL, 1000 LBS	=	535.272
RESERVE FUEL, LBS	=	39058.282
MISSION FUEL, 1000 LBS	=	496.213
AVERAGE MISSION RANGE FACTOR, TAXI-CLIMB-CRUISE	=	20505.706
LOITER TIME, HRS.	=	16.018
LOITER RADIUS, N. MI.	=	209.382
ZERO LOITER TIME RADIUS, N MI.	=	3589.273
WING LOADING, PSF	=	115.000
THRUST TO WEIGHT RATIO	=	.176
TAKEOFF GROSS WEIGHT, 1000 LBS	=	1680.000
OPERATING WEIGHT, 1000 LBS	=	744.728
TAKE OFF DISTANCE, FEET	=	8717.451
LANDING DISTANCE, FEET	=	3386.692
WING AREA, SQ. FT.	=	14608.696
CRUISE OUT RANGE FACTOR, NM	=	21313.554
CRUISE OUT SFC	=	.617
CRUISE OUT L/D	=	30.771
CRUISE OUT DRAG	=	53351.212
C O THRUST AVAILABLE, LBS	=	66715.086

:G).	LEG NAME	CONFIG	POWER	DIST.	TIME	INT. WEIGHT	INT. MACH	INT. ALT.	FINAL WEIGHT	FI MAC
1	TAKEOF3	1.0	6.0	.0	.052	1680000	.000	.0	1675943	.0
2	MAXRCL	1.0	5.0	209.4	.557	1675943	.435	.0	1641649	.7
	CRUISE3	1.0	6.0	6969.2	15.097	1641649	.805	37966.1	1183787	.8
	LOITER	1.0	6.0	.0	.500	1183787	.268	.0	1171492	.2
	RUISE2	1.0	6.0	209.4	.466	1195856	.784	41008.4	1183787	.7
6	LOITER	1.0	6.0	.0	16.018	1641649	.765	37957.5	1195856	.8

****CONFIGURATION CHARACTERISTICS ****

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	3724.138
AERODYNAMIC REFERENCE	3724.138
WETTED	6210.982
GLOVE	.000
YAHUDI	.000
AILERONS	131.082
SPOILERS	158.156
SPAN, FEET	195.854
TRAPEZOIDAL CHORDS, FEET	
ROOT	27.385
S.O.B.	25.223
TIP	10.645
MGC	20.238
CHORD OF THE CONSTANT SECTION	25.711
SWEEPS, DEGREES	
LEADING EDGE	10.000
QUARTER CHORD	7.609
TRAILING EDGE	.306
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	10.300
AERO REF. ASPECT RATIO	10.300
TRAPEZOIDAL TAPER RATIO	.389
AERO REF. TAPER RATIO	.4220
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	140335
BODY	0
TOTAL	140335
FUSELAGE - - -	
LENGTH, FT.	177.503
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	11933.467
AERODYNAMIC WETTED AREA	11266.136
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	7.018
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEPANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

****CONFIGURATION CHARACTERISTICS - 1****

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	859.902
EXPOSED PLANFORM	737.944
WETTED	1494.553
SPAN, FEET	56.658
CHORD, FEET	
ROOT	21.858
TIP	8.496
MOMENT ARM, FEET	82.539
LEADING EDGE SWEEP	10.000
AVERAGE T/C	.0920
TAPER RATIO	.389
ASPECT RATIO	3.733
VOLUME COEFFICIENT	.942

VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	533.634
EXPOSED PLANFORM	533.634
WETTED	1083.348
HEIGHT, FEET	31.110
CHORD, FEET	
ROOT	24.704
TIP	9.602
MOMENT ARM, FEET	81.297
LEADING EDGE SWEEP	10.000
AVERAGE T/C	.1000
TAPER RATIO	.389
ASPECT RATIO	1.814
VOLUME COEFFICIENT	.059

NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100

ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	[redacted] STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	.900
SFC CONSERVATISM	1.050

****CONFIGURATION CHARACTERISTICS - 2****

LANDING GEAR - - -	
NO. MAIN TIRES	16.000
MAIN,TRUNION TO AXLE	75.000
NOSE,TRUNION TO AXLE	75.000
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	1145.186
L/D	5.000
CARGO COMPARTMENT- - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	104.167
COMPARTMENT VOLUME	26666.667
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	200000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

GROUP WEIGHT SUMMARY

****
* MODEL 1044.000 *
****

WING	60454
HORIZONTAL TAIL	6093
VERTICAL TAIL	3705
BODY	72221
LANDING GEAR	23617
NACELLE STRUCTURE	5466
STRUCTURE	158518
ENGINE	15867
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	1750
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	4416
PROPULSION	23022
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	5890
HYDRAULICS	2608
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	5620
AIR COND. AND ANTI-ICING	3778
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	28725
WEIGHT EMPTY	210266
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	203
UNAVAILABEL FUEL	281
NONEXPENDABLE USEFUL LOAD	2124
OPERATING WEIGHT	212390
MISSION GROSS WEIGHT	540000
AMPR WEIGHT	180095

DESIGN # 7

MISSION SUMMARY DATA FOR MISSION FERRY1

FERRY MISSION GROSS WEIGHT, 1000 LBS.	=	540.000
FERRY PAYLOAD, 1000 LBS	=	200.000
FERRY RANGE, N.M.	=	3618.123
TOTAL FERRY FUEL, 1000 LBS	=	127.610
RESERVE FUEL, LBS	=	12065.993
MISSION FUEL, 1000 LBS	=	115.544
AVERAGE MISSION RANGE FACTOR, TAXI-CLIMB-CRUISE	=	15027.811
LOITER TIME, HRS.	=	8.055
LOITER RADIUS, N. MI.	=	141.769
ZERO LOITER TIME RADIUS, N MI.	=	1809.061
WING LOADING, PSF	=	145.000
THRUST TO WEIGHT RATIO	=	.221
TAKEOFF GROSS WEIGHT, 1000 LBS	=	540.000
OPERATING WEIGHT, 1000 LBS	=	212.390
TAKE OFF DISTANCE, FEET	=	7999.538
LANDING DISTANCE, FEET	=	4002.261
WING AREA, SQ. FT.	=	3724.138
CRUISE OUT RANGE FACTOR, NM	=	15879.767
CRUISE OUT SFC	=	.612
CRUISE OUT L/D	=	23.290
CRUISE OUT DRAG	=	22684.479
C G THRUST AVAILABLE, LBS	=	30999.246

LEG NO.	LEG NAME	CONFIG	POWER	DIST.	TIME	INT. WEIGHT	INT. MACH	INT. ALT.	FINAL WEIGHT
1	TAKEOF3	1.0	6.0	.0	.052	540000	.000	.0	538381
2	MAXRCL	1.0	5.0	141.8	.385	538381	.435	.0	528332
3	CRUISE3	1.0	6.0	3476.4	7.766	528332	.780	34634.1	424456
4	LOITER	1.0	6.0	.0	.500	424456	.299	.0	418770
	CRUISE2	1.0	6.0	141.8	.318	428304	.777	38563.2	42445
6	LOITER	1.0	6.0	.0	8.055	528332	.736	34625.7	428304

****CONFIGURATION CHARACTERISTICS ****

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	4517.241
AERODYNAMIC REFERENCE	4517.241
WETTED	7675.859
GLOVE	.000
YAHUDI	.000
AILERONS	161.597
SPOILERS	169.412
SPAN, FEET	215.703
TRAPEZOIDAL CHORDS, FEET	
ROOT	30.161
S.O.B.	27.999
TIP	11.723
MGC	22.269
CHORD OF THE CONSTANT SECTION	28.317
SWEEPS, DEGREES	
LEADING EDGE	10.000
QUARTER CHORD	7.509
TRAILING EDGE	.306
GLOVE LEADING EDGE	45.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	10.300
AERO REF. ASPECT RATIO	10.300
TRAPEZOIDAL TAPER RATIO	.389
AERO REF. TAPER RATIO	.4187
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	187472
BODY	22075
TOTAL	209547
FUSELAGE - - -	
LENGTH, FT.	177.503
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	11933.467
AERODYNAMIC WETTED AREA	11163.592
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	7.018
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEP ANGLE	4.500
AFT BODY UPSWEEP AREA	671.474

DESIGN # 8

****CONFIGURATION CHARACTERISTICS - 1****

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	1066.597
EXPOSED PLANFORM	915.324
WETTED	1853.800
SPAN, FEET	63.101
CHORD, FEET	
ROOT	24.344
TIP	9.462
MOMENT ARM, FEET	62.539
LEADING EDGE SWEEP	10.000
AVERAGE T/C	.0920
TAPER RATIO	.389
ASPECT RATIO	3.733
VOLUME COEFFICIENT	.874
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	712.878
EXPOSED PLANFORM	712.578
WETTED	1447.236
HEIGHT, FEET	35.958
CHORD, FEET	
ROOT	25.553
TIP	11.098
MOMENT ARM, FEET	81.297
LEADING EDGE SWEEP	10.000
AVERAGE T/C	.1000
TAPER RATIO	.389
ASPECT RATIO	1.914
VOLUME COEFFICIENT	.059
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	[redacted] STRDLGC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	1.092
SFC CONSERVATISM	1.050

****CONFIGURATION CHARACTERISTICS - 2****

LANDING GEAR - - -	
NO. MAIN TIRES	16.000
MAIN.TRUNION TO AXLE	75.000
NOSE.TRUNION TO AXLE	75.000
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	1290.808
L/D	5.000
CARGO COMPARTMENT- - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	104.167
COMPARTMENT VOLUME	26666.667
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	200000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

GROUP WEIGHT SUMMARY

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* MODEL 1044.00C *
****

WING	75457
HORIZONTAL TAIL	7936
VERTICAL TAIL	5395
BODY	75536
LANDING GEAR	27556
NACELLE STRUCTURE	6547
STRUCTURE	183995
ENGINE	20197
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	2314
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	5356
PROPULSION	28557
AUXILIARY POWER UNIT	430
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	6402
HYDRAULICS	3214
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS & EQUIP.	5560
AIR COND. AND ANTI-ICING	3790
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	30296
WEIGHT EMPTY	243147
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	246
UNAVAILABLE FUEL	419
NONEXPENDABLE USEFUL LOAD	2305
OPERATING WEIGHT	245452
MISSION GROSS WEIGHT	655000
AMPR WEIGHT	206481

MISSION SUMMARY DATA FOR MISSION FERRY1

FERRY MISSION GROSS WEIGHT, 1000 LBS.	=	655.000
FERRY PAYLOAD, 1000 LBS	=	200.000
FERRY RANGE, N.M.	=	5520.009
TOTAL FERRY FUEL, 1000 LBS	=	209.548
RESERVE FUEL, LBS	=	16685.372
MISSION FUEL, 1000 LBS	=	192.862
AVERAGE MISSION RANGE FACTOR, TAXI-CLIMB-CRUISE	=	15626.930
LOITER TIME, HRS.	=	12.770
LOITER RADIUS, N. MI.	=	130.619
ZERO LOITER TIME RADIUS, N MI.	=	2760.005
WING LOADING, PSF	=	145.000
THRUST TO WEIGHT RATIO	=	.221
TAKEOFF GROSS WEIGHT, 1000 LBS	=	655.000
OPERATING WEIGHT, 1000 LBS	=	245.452
TAKE OFF DISTANCE, FEET	=	7999.538
LANDING DISTANCE, FEET	=	3686.988
WING AREA, SQ. FT.	=	4517.241
CRUISE OUT RANGE FACTOR, NM	=	16412.261
CRUISE OUT SFC	=	.633
CRUISE OUT L/D	=	23.329
CRUISE OUT DRAG	=	27509.929
C.O THRUST AVAILABLE, LBS	=	27509.929

SEG NO.	LEG NAME	CONFIG	POWER	DIST.	TIME	INT. WEIGHT	INT. MACH	INT. ALT.	FINAL WEIGHT	FI MA
1	TAKEOFF	1.0	6.0	.0	.052	655000	.000	.0	653036	.0
2	[illegible]	1.2	5.0	130.6	.350	653036	.447	.0	641776	.7
	CRUISE	1.0	6.0	[illegible]344.4	12.103	641776	.776	33935.5	462136	.7
	LOITER	1.0	6.0	.0	.500	462136	.275	.0	455930	.2
	CRUISE2	1.0	6.0	130.6	.294	455904	.776	40442.9	462135	.7
6	LOITER	1.0	6.0	.0	12.770	641776	.728	33957.4	465904	.6

****CONFIGURATION CHARACTERISTICS ****

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	5272.727
AERODYNAMIC REFERENCE	5272.727
WETTED	9132.473
GLOVE	.000
YAHUDI	.000
AILERONS	178.911
SPOILERS	204.901
SPAN, FEET	248.907
TRAPEZOIDAL CHORDS, FEET	
ROOT	32.438
S.O.B.	30.151
TIP	9.929
MGC	23.171
CHORD OF THE CONSTANT SECTION	30.187
SWEEPS, DEGREES	
LEADING EDGE	30.000
QUARTER CHORD	28.019
TRAILING EDGE	21.619
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	11.750
AERO REF. ASPECT RATIO	11.750
TRAPEZOIDAL TAPER RATIO	.306
AERO REF. TAPER RATIO	.3293
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	230728
BODY	0
TOTAL	230728
FUSELAGE - - -	
LENGTH, FT.	177.503
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	11933.467
AERODYNAMIC WETTED AREA	11243.016
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	7.018
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEPANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

DESIGN #9

****CONFIGURATION CHARACTERISTICS - 1****

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	1172.058
EXPOSED PLANFORM	1004.381
WETTED	2039.148
SPAN, FEET	66.746
CHORD, FEET	
ROOT	26.889
TIP	8.231
MOMENT ARM, FEET	82.539
LEADING EDGE SWEEP	30.000
AVERAGE T/C	.0920
TAPER RATIO	.306
ASPECT RATIO	3.801
VOLUME COEFFICIENT	.792
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	745.847
EXPOSED PLANFORM	745.847
WETTED	1516.064
HEIGHT, FEET	37.923
CHORD, FEET	
ROOT	30.116
TIP	9.218
MOMENT ARM, FEET	81.297
LEADING EDGE SWEEP	30.000
AVERAGE T/C	.1000
TAPER RATIO	.306
ASPECT RATIO	1.928
VOLUME COEFFICIENT	.046
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	[redacted] STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	.831
SFC CONSERVATISM	1.050

****CONFIGURATION CHARACTERISTICS - 2****

LANDING GEAR - - -	
NO. MAIN TIRES	16.000
MAIN,TRUNION TO AXLE	75.000
NOSE,TRUNION TO AXLE	75.000
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	1197.064
L/D	5.000
CARGO COMPARTMENT- - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	104.167
COMPARTMENT VOLUME	26666.667
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	200000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

GROUP WEIGHT SUMMARY

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*******************
* MODEL 1044.000 *
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WING	105944
HORIZONTAL TAIL	8940
VERTICAL TAIL	5461
BODY	73515
LANDING GEAR	25621
NACELLE STRUCTURE	5075
STRUCTURE	207490
ENGINE	14362
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	1678
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	4077
PROPULSION	21108
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	6588
HYDRAULICS	2818
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	5534
AIR COND. AND ANTI-ICING	3774
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	29744
WEIGHT EMPTY	258341
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	187
UNAVAILABEL FUEL	461
NONEXPENDABLE USEFUL LOAD	2289
OPERATING WEIGHT	260630
MISSION GROSS WEIGHT	580000
AMPR WEIGHT	229012

DESIGN #9

MISSION SUMMARY DATA FOR MISSION FERRY1

FERRY MISSION GROSS WEIGHT, 1000 LBS.	=	580.000
FERRY PAYLOAD, 1000 LBS	=	200.000
FERRY RANGE, N.M.	=	3596.024
TOTAL FERRY FUEL, 1000 LBS	=	119.370
RESERVE FUEL, LBS	=	11234.085
MISSION FUEL, 1000 LBS	=	108.136
AVERAGE MISSION RANGE FACTOR, TAXI-CLIMB-CRUISE	=	17427.933
LOITER TIME, HRS.	=	7.662
LOITER RADIUS, N. MI.	=	193.149
ZERO LOITER TIME RADIUS, N MI.	=	1798.012
WING LOADING, PSF	=	110.000
THRUST TO WEIGHT RATIO	=	.190
TAKEOFF GROSS WEIGHT, 1000 LBS	=	580.000
OPERATING WEIGHT, 1000 LBS	=	260.630
TAKE OFF DISTANCE, FEET	=	8042.109
LANDING DISTANCE, FEET	=	3527.478
WING AREA, SQ. FT.	=	5272.727
CRUISE OUT RANGE FACTOR, NM	=	18736.166
CRUISE OUT SFC	=	.610
CRUISE OUT L/D	=	26.984
CRUISE OUT DRAG	=	20969.416
C O THRUST AVAILABLE, LBS	=	25676.198

LEG NO.	LEG NAME	CONFIG	POWER	DIST.	TIME	INT. WEIGHT	INT. MACH	INT. ALT.	FINAL WEIGHT
1	TAKEOF3	1.0	6.0	.0	.052	580000	.000	.0	578505
2	MAXRCL	1.0	5.0	193.1	.555	578505	.391	.0	565840
3	CRUISE3	1.0	6.0	3402.9	7.480	565840	.793	36976.1	471964
4	LOITER	1.0	6.0	.0	.500	471964	.285	.0	466599
	CRUISE2	1.0	6.0	193.1	.442	476989	.763	37132.5	471964
6	LOITER	1.0	6.0	.0	7.662	565840	.736	36965.1	476989

****CONFIGURATION CHARACTERISTICS ****

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	6363.636
AERODYNAMIC REFERENCE	6363.636
WETTED	11190.858
GLOVE	.000
YAHUDI	.000
AILERONS	219.365
SPOILERS	244.248
SPAN, FEET	273.446
TRAPEZOIDAL CHORDS, FEET	
ROOT	35.636
S.O.B.	33.349
TIP	10.908
MGC	25.455
CHORD OF THE CONSTANT SECTION	33.163
SWEEPS, DEGREES	
LEADING EDGE	30.000
QUARTER CHORD	28.019
TRAILING EDGE	21.619
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	11.750
AERO REF. ASPECT RATIO	11.750
TRAPEZOIDAL TAPER RATIO	.306
AERO REF. TAPER RATIO	.3271
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	305919
BODY	0
TOTAL	305919
FUSELAGE - - -	
LENGTH, FT.	177.503
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	11933.467
AERODYNAMIC WETTED AREA	11134.997
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	7.018
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEPANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

****CONFIGURATION CHARACTERISTICS - 1****

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	1442.462
EXPOSED PLANFORM	1236.101
WETTED	2509.598
SPAN, FEET	74.047
CHORD, FEET	
ROOT	29.830
TIP	9.131
MOMENT ARM, FEET	82.539
LEADING EDGE SWEEP	30.000
AVERAGE T/C	.0920
TAPER RATIO	.306
ASPECT RATIO	3.801
VOLUME COEFFICIENT	.735
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	988.905
EXPOSED PLANFORM	988.905
WETTED	2010.122
HEIGHT, FEET	43.668
CHORD, FEET	
ROOT	34.678
TIP	10.615
MOMENT ARM, FEET	81.297
LEADING EDGE SWEEP	30.000
AVERAGE T/C	.1000
TAPER RATIO	.306
ASPECT RATIO	1.928
VOLUME COEFFICIENT	.046
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	[redacted] STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	1.003
SFC CONSERVATISM	1.050

****CONFIGURATION CHARACTERISTICS - 2****

```
LANDING GEAR - - -
     NO. MAIN TIRES                          16.000
     MAIN,TRUNION TO AXLE                    75.000
     NOSE,TRUNION TO AXLE                    75.000

GEAR POD - - -
     LENGTH                                  53.000
     WETTED AREA                           1345.094
     L/D                                      5.000

CARGO COMPARTMENT- - -
     COMPARTMENT HEIGHT                      16.000
     COMPARTMENT WIDTH                       16.000
     COMPARTMENT LENGTH                     104.167
     COMPARTMENT VOLUME                   26666.667
     PAYLOAD DENSITY                          7.500
     PAYLOAD WEIGHT                        200000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS
```

GROUP WEIGHT SUMMARY

****
* MODEL 1044.00C *
****

WING	131547
HORIZONTAL TAIL	11449
VERTICAL TAIL	7874
BODY	76803
LANDING GEAR	30175
NACELLE STRUCTURE	6048
STRUCTURE	243842
ENGINE	18168
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	2215
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	4921
PROPULSION	26294
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	7711
HYDRAULICS	3453
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	5674
AIR COND. AND ANTI-ICING	3784
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	31453
WEIGHT EMPTY	301588
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	226
UNAVAILABEL FUEL	612
NONEXPENDABLE USEFUL LOAD	2478
OPERATING WEIGHT	304066
MISSION GROSS WEIGHT	700000
AMPR WEIGHT	266691

DESIGN #10

MISSION SUMMARY DATA FOR MISSION FERRY1

FERRY MISSION GROSS WEIGHT, 1000 LBS.	=	700.000
FERRY PAYLOAD, 1000 LBS	=	200.000
FERRY RANGE, N.M.	=	5502.686
TOTAL FERRY FUEL, 1000 LBS	=	195.934
RESERVE FUEL, LBS	=	15586.162
MISSION FUEL, 1000 LBS	=	180.348
AVERAGE MISSION RANGE FACTOR, TAXI-CLIMB-CRUISE	=	18470.326
LOITER TIME, HRS.	=	12.142
LOITER RADIUS, N. MI.	=	194.689
ZERO LOITER TIME RADIUS, N MI.	=	2751.343
WING LOADING, PSF	=	110.000
THRUST TO WEIGHT RATIO	=	.190
TAKEOFF GROSS WEIGHT, 1000 LBS	=	700.000
OPERATING WEIGHT, 1000 LBS	=	304.066
TAKE OFF DISTANCE, FEET	=	8042.109
LANDING DISTANCE, FEET	=	3441.350
WING AREA, SQ. FT.	=	6363.636
CRUISE OUT RANGE FACTOR, NM	=	19393.297
CRUISE OUT SFC	=	.614
CRUISE OUT L/D	=	27.948
CRUISE OUT DRAG	=	24446.856
C O THRUST AVAILABLE, LBS	=	30340.894

LEG NO.	LEG NAME	CONFIG	POWER	DIST.	TIME	INT. WEIGHT	INT. MACH	INT. ALT.	FINAL WEIGHT	F M
1	TAKEOF3	1.0	6.0	.0	.052	700000	.000	.0	698196	.
2	MAXRCL	1.0	5.0	194.7	.546	698196	.412	.0	683251	.
[illegible]	CRUISE3	1.0	6.0	5308.0	11.530	683251	.803	37529.5	519652	.
4	LOITER	1.0	6.0	.0	.500	519652	.275	.0	513863	.
[illegible]	CRUISE2	1.0	6.0	194.7	.437	525156	.776	39562.8	519652	.
6	LOITER	1.0	6.0	.0	12.142	683251	.751	37520.1	525156	.

****CONFIGURATION CHARACTERISTICS ****

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	14963.504
AERODYNAMIC REFERENCE	14963.504
WETTED	27255.045
GLOVE	.000
YAHUDI	.000
AILERONS	671.678
SPOILERS	657.905
SPAN, FEET	345.988
TRAPEZOIDAL CHORDS, FEET	
ROOT	62.286
S.O.B.	59.503
TIP	24.211
MGC	46.031
CHORD OF THE CONSTANT SECTION	58.479
SWEEPS, DEGREES	
LEADING EDGE	10.000
QUARTER CHORD	6.917
TRAILING EDGE	-2.508
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	8.000
AERO REF. ASPECT RATIO	8.000
TRAPEZOIDAL TAPER RATIO	.389
AERO REF. TAPER RATIO	.4069
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	1282478
BODY	0
TOTAL	1282478
FUSELAGE - - -	
LENGTH, FT.	385.837
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	28475.896
AERODYNAMIC WETTED AREA	26698.198
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	15.254
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEPANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

****CONFIGURATION CHARACTERISTICS - 1****

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	3494.997
EXPOSED PLANFORM	2984.559
WETTED	6044.576
SPAN, FEET	112.561
CHORD, FEET	
ROOT	44.718
TIP	17.382
MOMENT ARM, FEET	179.414
LEADING EDGE SWEEP	10.000
AVERAGE T/C	.0920
TAPER RATIO	.389
ASPECT RATIO	3.625
VOLUME COEFFICIENT	.910
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	1807.253
EXPOSED PLANFORM	1807.253
WETTED	3669.194
HEIGHT, FEET	54.309
CHORD, FEET	
ROOT	47.926
TIP	18.629
MOMENT ARM, FEET	176.713
LEADING EDGE SWEEP	10.000
AVERAGE T/C	.1000
TAPER RATIO	.389
ASPECT RATIO	1.632
VOLUME COEFFICIENT	.062
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	[redacted] STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	3.247
SFC CONSERVATISM	1.050

****CONFIGURATION CHARACTERISTICS - 2****

LANDING GEAR - - -	
NO. MAIN TIRES	32.000
MAIN,TRUNION TO AXLE	217.410
NOSE,TRUNION TO AXLE	217.410
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	2618.661
L/D	5.000
CARGO COMPARTMENT- - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	312.500
COMPARTMENT VOLUME	80000.000
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	600000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

GROUP WEIGHT SUMMARY

****
* MODEL 1044.000 *
****

WING	287978
HORIZONTAL TAIL	33943
VERTICAL TAIL	16180
BODY	226059
LANDING GEAR	120673
NACELLE STRUCTURE	18446
STRUCTURE	649830
ENGINE	78380
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	4739
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	15928
PROPULSION	100538
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	17874
HYDRAULICS	11043
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	9394
AIR COND. AND ANTI-ICING	6083
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	55224
WEIGHT EMPTY	805592
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	732
UNAVAILABEL FUEL	2565
NONEXPENDABLE USEFUL LOAD	4937
OPERATING WEIGHT	810529
MISSION GROSS WEIGHT	2050000
AMPR WEIGHT	677464

DESIGN #11

MISSION SUMMARY DATA FOR MISSION FERRY1

FERRY MISSION GROSS WEIGHT, 1000 LBS.	= 2050.000
FERRY PAYLOAD, 1000 LBS	= 600.000
FERRY RANGE, N.M.	= 5465.964
TOTAL FERRY FUEL, 1000 LBS	= 639.471
RESERVE FUEL, LBS	= 51402.468
MISSION FUEL, 1000 LBS	= 588.068
AVERAGE MISSION RANGE FACTOR, TAXI-CLIMB-CRUISE	= 16167.608
LOITER TIME, HRS.	= 12.303
LOITER RADIUS, N. MI.	= 130.369
ZERO LOITER TIME RADIUS, N MI.	= 2732.982
WING LOADING, PSF	= 137.000
THRUST TO WEIGHT RATIO	= .210
TAKEOFF GROSS WEIGHT, 1000 LBS	= 2050.000
OPERATING WEIGHT, 1000 LBS	= 810.529
TAKE OFF DISTANCE, FEET	= 8008.160
LANDING DISTANCE, FEET	= 3734.102
WING AREA, SQ. FT.	= 14963.504
CRUISE OUT RANGE FACTOR, NM	= 16719.345
CRUISE OUT SFC	= .616
CRUISE OUT L/D	= 24.712
CRUISE OUT DRAG	= 81397.681
C C THRUST AVAILABLE, LBS	=119266.184

.EG NO.	LEG NAME	CONFIG	POWER	DIST.	TIME	INT. WEIGHT	INT. MACH	INT. ALT.	FINAL WEIGHT	FI MA
1	TAKEOF3	1.0	6.0	.0	.052	2050000	.000	.0	2044160	.
2	MAXRCL	1.0	5.0	130.4	.330	2044160	.477	.0	2011510	.7
	CRUISE3	1.0	6.0	5335.6	11.862	2011510	.780	31900.8	1461932	.7
4	LOITER	1.0	6.0	.0	.500	1461932	.285	.0	1442503	.2
	CRUISE2	1.0	6.0	130.4	.292	1473568	.777	37764.5	1461932	.7
6	LOITER	1.0	6.0	.0	12.303	2011510	.743	31895.6	1473568	.6

****CONFIGURATION CHARACTERISTICS ****

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	19038.462
AERODYNAMIC REFERENCE	19038.462
WETTED	35119.621
GLOVE	.000
YAHUDI	.000
AILERONS	872.059
SPOILERS	823.869
SPAN, FEET	390.266
TRAPEZOIDAL CHORDS, FEET	
ROOT	70.257
S.O.B.	67.474
TIP	27.309
MGC	51.921
CHORD OF THE CONSTANT SECTION	65.963
SWEEPS, DEGREES	
LEADING EDGE	10.000
QUARTER CHORD	6.917
TRAILING EDGE	-2.508
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	8.000
AERO REF. ASPECT RATIO	8.000
TRAPEZOIDAL TAPER RATIO	.389
AERO REF. TAPER RATIO	.4047
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	1840551
BODY	0
TOTAL	1840551
FUSELAGE - - -	
LENGTH, FT.	385.837
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	28475.896
AERODYNAMIC WETTED AREA	26400.706
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	15.254
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEPANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

****CONFIGURATION CHARACTERISTICS - 1****

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	4568.485
EXPOSED PLANFORM	3901.265
WETTED	7901.167
SPAN, FEET	128.692
CHORD, FEET	
ROOT	51.126
TIP	19.873
MOMENT ARM, FEET	179.414
LEADING EDGE SWEEP	10.000
AVERAGE T/C	.0920
TAPER RATIO	.389
ASPECT RATIO	3.625
VOLUME COEFFICIENT	.829
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	2296.956
EXPOSED PLANFORM	2296.956
WETTED	4663.419
HEIGHT, FEET	61.226
CHORD, FEET	
ROOT	54.030
TIP	21.002
MOMENT ARM, FEET	176.713
LEADING EDGE SWEEP	10.000
AVERAGE T/C	.1000
TAPER RATIO	.389
ASPECT RATIO	1.632
VOLUME COEFFICIENT	.055
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	[redacted] STEDLEL
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	3.453
SFC CONSERVATISM	1.050

****CONFIGURATION CHARACTERISTICS - 2****

LANDING GEAR - - -	
NO. MAIN TIRES	32.000
MAIN,TRUNION TO AXLE	214.548
NOSE,TRUNION TO AXLE	214.548
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	2943.124
L/D	5.000
CARGO COMPARTMENT- - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	312.500
COMPARTMENT VOLUME	80000.000
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	600000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

GROUP WEIGHT SUMMARY

****
* MODEL 1044.000 *
****

WING	376005
HORIZONTAL TAIL	46420
VERTICAL TAIL	22065
BODY	236185
LANDING GEAR	141720
NACELLE STRUCTURE	19577
STRUCTURE	776000
ENGINE	85199
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	5886
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	16941
PROPULSION	109016
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	20689
HYDRAULICS	13540
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	9440
AIR COND. AND ANTI-ICING	6090
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	60588
WEIGHT EMPTY	947603
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	778
UNAVAILABEL FUEL	3681
NONEXPENDABLE USEFUL LOAD	6099
OPERATING WEIGHT	953703
MISSION GROSS WEIGHT	2475000
AMPR WEIGHT	805583

MISSION SUMMARY DATA FOR MISSION FERRY1

FERRY MISSION GROSS WEIGHT, 1000 LBS.	= 2475.000
FERRY PAYLOAD, 1000 LBS	= 600.000
FERRY RANGE, N.M.	= 7231.930
TOTAL FERRY FUEL, 1000 LBS	= 921.297
RESERVE FUEL, LBS	= 66242.562
MISSION FUEL, 1000 LBS	= 855.054
AVERAGE MISSION RANGE FACTOR, TAXI-CLIMB-CRUISE	= 17062.560
LOITER TIME, HRS.	= 16.552
LOITER RADIUS, N. MI.	= 159.580
ZERO LOITER TIME RADIUS, N MI.	= 3615.965
WING LOADING, PSF	= 130.000
THRUST TO WEIGHT RATIO	= .185
TAKEOFF GROSS WEIGHT, 1000 LBS	= 2475.000
OPERATING WEIGHT, 1000 LBS	= 953.703
TAKE OFF DISTANCE, FEET	= 8887.364
LANDING DISTANCE, FEET	= 3498.362
WING AREA, SQ. FT.	= 19038.462
CRUISE OUT RANGE FACTOR, NM	= 17515.255
CRUISE OUT TFC	= .614
CRUISE OUT L/D	= 25.947
CRUISE OUT DRAG	= 93491.927
C G THRUST AVAILABLE, LBS	=127663.121

LEG NO.	LEG NAME	CONFIG	POWER	DIST.	TIME	INT. WEIGHT	INT. MACH	INT. ALT.	FINAL WEIGHT
1	TAKEOF3	1.0	6.0	.0	.052	2475000	.000	.0	2468769
2	MAXRCL	1.0	5.0	159.6	.411	2468769	.468	.0	2425833
3	CRUISE3	1.0	6.0	7072.3	15.741	2425833	.777	31709.9	1619946
4	LOITER	1.0	6.0	.0	.500	1619946	.269	.0	1599768
5	CRUISE2	1.0	6.0	159.6	.359	1635027	.774	39263.4	1619946
6	LOITER	1.0	6.0	.0	16.552	2425833	.740	31704.7	1635027

****CONFIGURATION CHARACTERISTICS ****

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	16917.293
AERODYNAMIC REFERENCE	16917.293
WETTED	31571.260
GLOVE	.000
YAHUDI	.000
AILERONS	626.455
SPOILERS	602.424
SPAN, FEET	450.564
TRAPEZOIDAL CHORDS, FEET	
ROOT	57.495
S.O.B.	55.255
TIP	17.599
MGC	41.069
CHORD OF THE CONSTANT SECTION	53.505
SWEEPS, DEGREES	
LEADING EDGE	30.000
QUARTER CHORD	28.061
TRAILING EDGE	21.805
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	18.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	12.000
AERO REF. ASPECT RATIO	12.000
TRAPEZOIDAL TAPER RATIO	.306
AERO REF. TAPER RATIO	.3185
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	1312117
BODY	0
TOTAL	1312117
FUSELAGE - - -	
LENGTH, FT.	385.837
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	28475.896
AERODYNAMIC WETTED AREA	26589.978
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	15.254
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEPANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

****CONFIGURATION CHARACTERISTICS - 1****

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	3590.667
EXPOSED PLANFORM	3078.559
WETTED	6250.284
SPAN, FEET	117.006
CHORD, FEET	
ROOT	46.991
TIP	14.384
MOMENT ARM, FEET	179.414
LEADING EDGE SWEEP	30.000
AVERAGE T/C	.0920
TAPER RATIO	.306
ASPECT RATIO	3.813
VOLUME COEFFICIENT	.927
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	2214.218
EXPOSED PLANFORM	2214.218
WETTED	4500.893
HEIGHT, FEET	65.676
CHORD, FEET	
ROOT	51.626
TIP	15.803
MOMENT ARM, FEET	176.713
LEADING EDGE SWEEP	30.000
AVERAGE T/C	.1000
TAPER RATIO	.306
ASPECT RATIO	1.948
VOLUME COEFFICIENT	.051
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	[redacted] STEDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	3.682
SFC CONSERVATISM	1.050

****CONFIGURATION CHARACTERISTICS - 2****

LANDING GEAR - - -	
NO. MAIN TIRES	32.000
MAIN,TRUNION TO AXLE	236.209
NOSE,TRUNION TO AXLE	236.209
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	2774.247
L/D	5.000
CARGO COMPARTMENT- - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	312.500
COMPARTMENT VOLUME	80000.000
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	600000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

GROUP WEIGHT SUMMARY

****
* MODEL 1044.COG *
****

WING	502675
HORIZONTAL TAIL	38544
VERTICAL TAIL	22713
BODY	230631
LANDING GEAR	138401
NACELLE STRUCTURE	20832
STRUCTURE	881492
ENGINE	92321
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	4575
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	18065
PROPULSION	115951
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	20629
HYDRAULICS	12213
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	9417
AIR COND. AND ANTI-ICING	6097
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	59185
WEIGHT EMPTY	1056628
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	830
UNAVAILABEL FUEL	2624
NONEXPENDABLE USEFUL LOAD	5094
OPERATING WEIGHT	1061722
MISSION GROSS WEIGHT	2250000
AMPR WEIGHT	909068

DESIGN #13

MISSION SUMMARY DATA FOR MISSION FERRY1

FERRY MISSION GROSS WEIGHT, 1000 LBS.	=	2250.000
FERRY PAYLOAD, 1000 LBS	=	600.000
FERRY RANGE, N.M.	=	5394.996
TOTAL FERRY FUEL, 1000 LBS	=	588.278
RESERVE FUEL, LBS	=	49543.061
MISSION FUEL, 1000 LBS	=	538.734
AVERAGE MISSION RANGE FACTOR, TAXI-CLIMB-CRUISE	=	19711.560
LOITER TIME, HRS.	=	11.673
LOITER RADIUS, N. MI.	=	128.867
ZERO LOITER TIME RADIUS, N MI.	=	2697.498
WING LOADING, PSF	=	133.000
THRUST TO WEIGHT RATIO	=	.217
TAKEOFF GROSS WEIGHT, 1000 LBS	=	2250.000
OPERATING WEIGHT, 1000 LBS	=	1061.722
TAKE OFF DISTANCE, FEET	=	8291.054
LANDING DISTANCE, FEET	=	3970.521
WING AREA, SQ. FT.	=	16917.293
CRUISE OUT RANGE FACTOR, NM	=	20638.775
CRUISE OUT SFC	=	.627
CRUISE OUT L/D	=	30.076
CRUISE OUT DRAG	=	73436.642
C O THRUST AVAILABLE, LBS	=	117952.702

LEG NO.	LEG NAME	CONFIG	POWER	DIST.	TIME	INT. WEIGHT	INT. MACH	INT. ALT.	FINAL WEIGHT
1	TAKEOF3	1.0	6.0	.0	.052	2250000	.000	.0	2243377
2	MAXRCL	1.0	5.0	128.9	.322	2243377	.469	.0	2208669
3	CRUISE3	1.0	6.0	5266.1	11.112	2208669	.826	36047.2	1711266
4	LOITER	1.0	6.0	.0	.500	1711266	.299	.0	1691136
5	CRUISE2	1.0	6.0	128.9	.272	1722159	.826	41256.8	1711266
6	LOITER	1.0	6.0	.0	11.673	2208669	.785	36043.6	1722159

****CONFIGURATION CHARACTERISTICS ****

WING - - -	
AREAS	
TRAPEZOIDAL REFERENCE	20625.000
AERODYNAMIC REFERENCE	20625.000
WETTED	38818.840
GLOVE	.000
YAHUDI	.000
AILERONS	776.573
SPOILERS	724.927
SPAN, FEET	497.494
TRAPEZOIDAL CHORDS, FEET	
ROOT	63.483
S.O.B.	61.244
TIP	19.432
MGC	45.347
CHORD OF THE CONSTANT SECTION	59.078
SWEEPS, DEGREES	
LEADING EDGE	30.000
QUARTER CHORD	28.061
TRAILING EDGE	21.805
GLOVE LEADING EDGE	46.500
YAHUDI TRAILING EDGE	16.000
AVERAGE,EXPOSED,STREAMWISE T/C	.1000
STRUCTURAL T/C	.1439
TRAPEZOIDAL ASPECT RATIO	12.000
AERO REF. ASPECT RATIO	12.000
TRAPEZOIDAL TAPER RATIO	.306
AERO REF. TAPER RATIO	.3173
DESIGN LIFT COEFFICIENT	.400
FUEL	
WING	1766312
BODY	0
TOTAL	1766312
FUSELAGE - - -	
LENGTH, FT.	385.837
MAXIMUM WIDTH	25.294
MAXIMUM DEPTH	25.294
STRUCTURAL WETTED AREA	28475.896
AERODYNAMIC WETTED AREA	26343.533
NOSE FINENESS RATIO	1.500
BODY FINENESS RATIO	15.254
AFT BODY CLOSURE ANGLE	15.000
AFT BODY UPSWEEPANGLE	8.500
AFT BODY UPSWEEP AREA	671.474

****CONFIGURATION CHARACTERISTICS - 1****

HORIZONTAL TAIL - - -	
AREA, FT2	
REFERENCE	4477.888
EXPOSED PLANFORM	3639.242
WETTED	7794.671
SPAN, FEET	130.665
CHORD, FEET	
ROOT	52.477
TIP	16.063
MOMENT ARM, FEET	179.414
LEADING EDGE SWEEP	30.000
AVERAGE T/C	.0920
TAPER RATIO	.306
ASPECT RATIO	3.813
VOLUME COEFFICIENT	.859
VERTICAL TAIL - - -	
AREA, FT2	
REFERENCE	2523.736
EXPOSED PLANFORM	2523.736
WETTED	5130.058
HEIGHT, FEET	70.116
CHORD, FEET	
ROOT	55.116
TIP	16.871
MOMENT ARM, FEET	176.713
LEADING EDGE SWEEP	30.000
AVERAGE T/C	.1000
TAPER RATIO	.306
ASPECT RATIO	1.948
VOLUME COEFFICIENT	.043
NACELLES - - -	
NUMBER	4.000
FINENESS RATIO	2.560
CLOSURE ANGLE	12.000
D(EXIT)/D(MAX)	.624
DESIGN INLET MACH NO.	.6500
(ARC HT)/(LENGTH)	.052
STRUT T/C	.100
ENGINES - - -	
ENGINE MANUFACTURER	GENELEC
ENGINE MODEL	[redacted] STRDLEC
SEA LEVEL REFERENCE THRUST	33150.000
SCALE FACTOR	3.643
SFC CONSERVATISM	1.050

****CONFIGURATION CHARACTERISTICS - 2****

LANDING GEAR - - -	
NO. MAIN TIRES	32.000
MAIN,TRUNION TO AXLE	233.992
NOSE,TRUNION TO AXLE	233.992
GEAR POD - - -	
LENGTH	53.000
WETTED AREA	3063.278
L/D	5.000
CARGO COMPARTMENT- - -	
COMPARTMENT HEIGHT	16.000
COMPARTMENT WIDTH	16.000
COMPARTMENT LENGTH	312.500
COMPARTMENT VOLUME	80000.000
PAYLOAD DENSITY	7.500
PAYLOAD WEIGHT	600000.0

PAYLOAD SIZED TO INPUT COMPARTMENT DIMENSIONS

GROUP WEIGHT SUMMARY

****
* MODEL 1044.000 *
****

WING	626311
HORIZONTAL TAIL	49875
VERTICAL TAIL	26915
BODY	239560
LANDING GEAR	158919
NACELLE STRUCTURE	20620
STRUCTURE	1036912
ENGINE	91110
ENGINE ACC. AND INSTL.	590
FUEL SYSTEM	5511
ENGINE CONTROLS	200
STARTING SYSTEM	200
THRUST REVERSERS	17875
PROPULSION	115486
AUXILIARY POWER UNIT	930
INSTR. AND NAV EQUIP.	960
SURFACE CONTROLS	23384
HYDRAULICS	14519
ELECTRICAL	3440
AVIONICS	3450
ARMAMENT	0
FURNISHINGS EQUIP.	9455
AIR COND. AND ANTI-ICING	6095
BLC DISTRIBUTION	0
AUXILIARY GEAR	2050
FIXED EQUIPMENT	64283
WEIGHT EMPTY	1216682
CREW	1290
CREW PROVISIONS	350
OIL AND TRAPPED OIL	821
UNAVAILABEL FUEL	3533
NONEXPENDABLE USEFUL LOAD	5994
OPERATING WEIGHT	1222676
MISSION GROSS WEIGHT	2640000
AMPR WEIGHT	1063020

DESIGN #14

MISSION SUMMARY DATA FOR MISSION FERRY1

FERRY MISSION GROSS WEIGHT, 1000 LBS.	=	2640.000
FERRY PAYLOAD, 1000 LBS	=	600.000
FERRY RANGE, N.M.	=	7112.466
TOTAL FERRY FUEL, 1000 LBS	=	817.324
RESERVE FUEL, LBS	=	61100.377
MISSION FUEL, 1000 LBS	=	756.224
AVERAGE MISSION RANGE FACTOR, TAXI-CLIMB-CRUISE	=	21073.950
LOITER TIME, HRS.	=	15.548
LOITER RADIUS, N. MI.	=	171.969
ZERO LOITER TIME RADIUS, N MI.	=	3556.233
WING LOADING, PSF	=	128.000
THRUST TO WEIGHT RATIO	=	.183
TAKEOFF GROSS WEIGHT, 1000 LBS	=	2640.000
OPERATING WEIGHT, 1000 LBS	=	1222.676
TAKE OFF DISTANCE, FEET	=	9887.526
LANDING DISTANCE, FEET	=	3757.315
WING AREA, SQ. FT.	=	20625.000
CRUISE OUT RANGE FACTOR, NM	=	21866.734
CRUISE OUT SFC	=	.624
CRUISE OUT L/D	=	31.437
CRUISE OUT DRAG	=	82307.232
C O THRUST AVAILABLE, LBS	=	115826.675

LEG NO.	LEG NAME	CONFIG	POWER	DIST.	TIME	INT. WEIGHT	INT. MACH	INT. ALT.	FINAL WEIGHT
1	TAKEOF3	1.0	6.0	.0	.052	2640000	.000	.0	2633446
2	MAXRCL	1.0	5.0	172.0	.439	2633446	.457	.0	2587464
3	CRUISE3	1.0	6.0	6940.5	14.687	2587464	.824	36255.2	1883776
4	LOITER	1.0	6.0	.0	.500	1883776	.288	.0	1863542
	CRUISE2	1.0	6.0	172.0	.366	1898995	.819	41507.1	1883776
6	LOITER	1.0	6.0	.0	15.548	2587464	.782	36246.8	1898995

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APPENDIX C

STEDLEC ENGINE CHARACTERISTICS

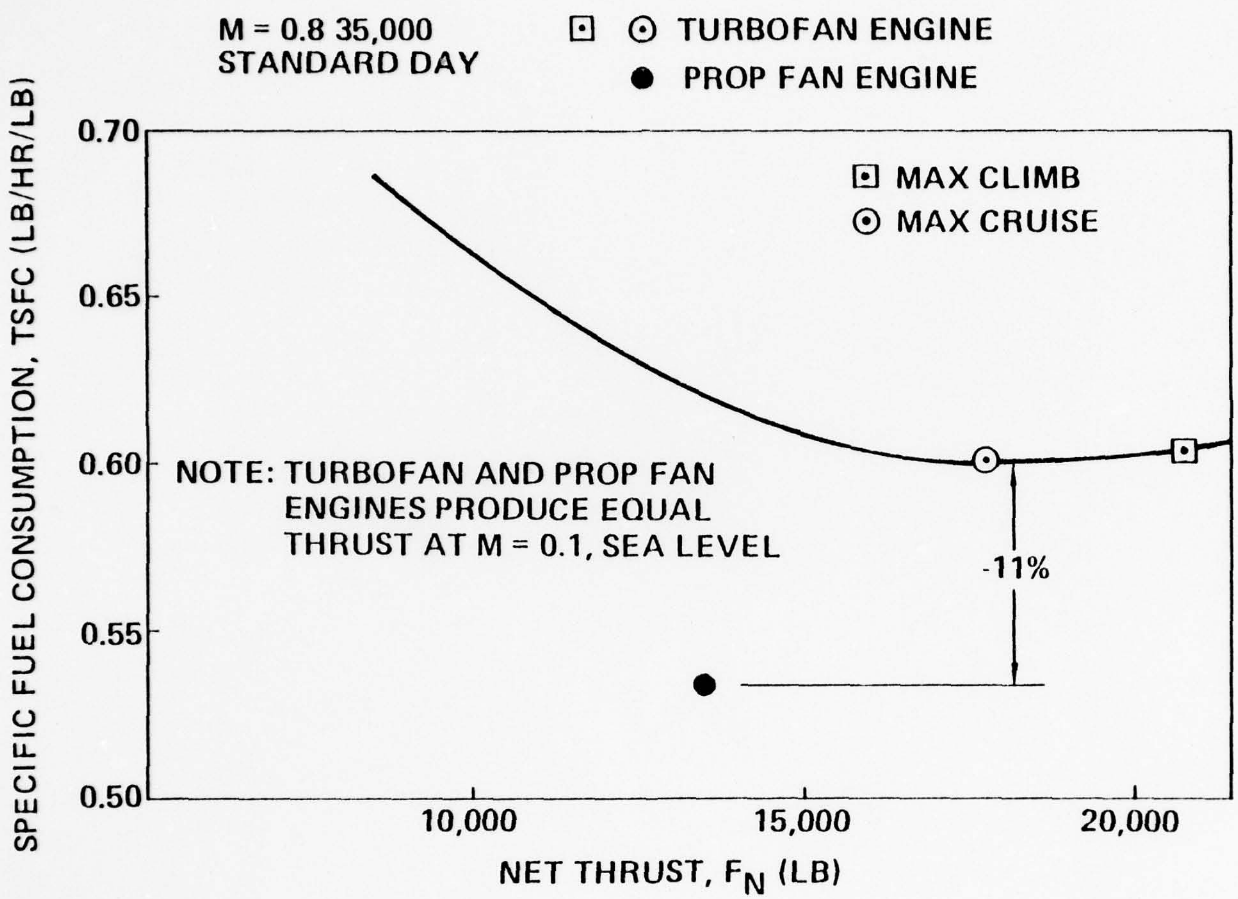

Figure 1 Stedlac Engine Installed Performance

Improved fan aerodynamics

Composite fan blades and frame

Advanced directionally solidified turbine blades

HPT clearance control

Ceramic stationary turbine components

Mixed flow Nacelle

Cycle Parameter Comparison

	STEDLEC	CF6-50C
Turbine in let temperature (SLS, takeoff)	2600°F	2350°F
Overall pressure ratio (Takeoff)	30:1	29:1
Fan pressure ratio	1.7:1	1.7:1
By pass ratio	7:1	4.4:1

At Equal Thrust

$$\frac{\text{STEDLEC weight}}{\text{CF6-50C weight}} = 88\%$$

$$\frac{\text{STEDLEC TSFC}}{\text{CF6-50C TSFC}} = 90\%$$

Figure 2 Summary Stedlac Engine Technology Advancement

AD-A044 319 BOEING AEROSPACE CO SEATTLE WASH BOEING MILITARY AIR--ETC F/G 1/3
INNOVATIVE AIRCRAFT DESIGN STUDY. TASK II. DESIGN SUBTASK I. CH--ETC(U)
JUN 77 F33615-76-C-0122

UNCLASSIFIED NL

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	Turbofan Basic	Turbofan Scaled*
Takeoff thrust, SLS	33,150	81,800
Takeoff thrust, SL, M = 0.1	29,650	71,540
Bypass ratio	7	7
Fan pressure ratio - design	1.7	1.7
Overall pressure ratio - design	38:1	38:1
Turbine inlet temperature (Takeoff @ 86°F, SLS)	1600°F	2600°F
Exhaust system	Mixed	Mixed
Fan tip diameter	78.8"	124.2"
Bare engine weight	4515 lbs	14,100 lbs
Thrust/weight (SLS, takeoff)	7.3	5.8
Description	Advanced technology 2-spool turbofan	

*Scaled using General Electric scaling factors:

$$D = \left(\frac{81{,}700}{33{,}150}\right)^{.5} 78.8''$$

$$Wgt = \left(\frac{81{,}700}{33{,}150}\right)^{1.25} 4{,}515 \text{ lbs}$$

	Prop Fan (Scaled)**
Takeoff thrust, SLS	47,420
Takeoff thrust, SL, M = 0.1	71,540
Overall pressure ratio - design	38:1
Turbine inlet temperature (Takeoff @ 86°F, SLS)	2600°F
Prop diameter	25.6'
Bare engine weight	8950 lbs
Gearbox weight	7290 lbs
Prop weight	4500 lbs
Description	Advanced technology 2-spool turboprop with prop fan

** • Core engine sized to match turbofan engine thrust at TO,SL, M = 0.1

• Prop dimensions and weight, and gearbox weight derived from Hamilton Standard information

Figure 3 Stedlac Engine Characteristics

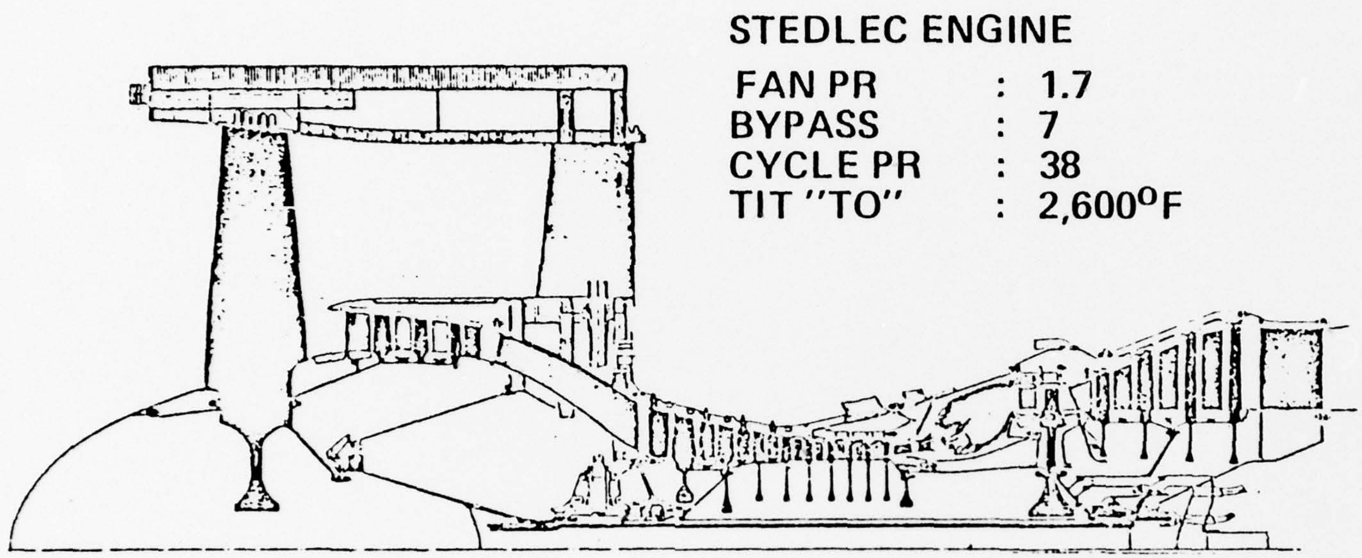

Figure 4 Stedlac Engine Section View

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APPENDIX D

CONFIGURATION CHARACTERISTICS FOR A CIRCULAR CROSS SECTION FUSELAGE

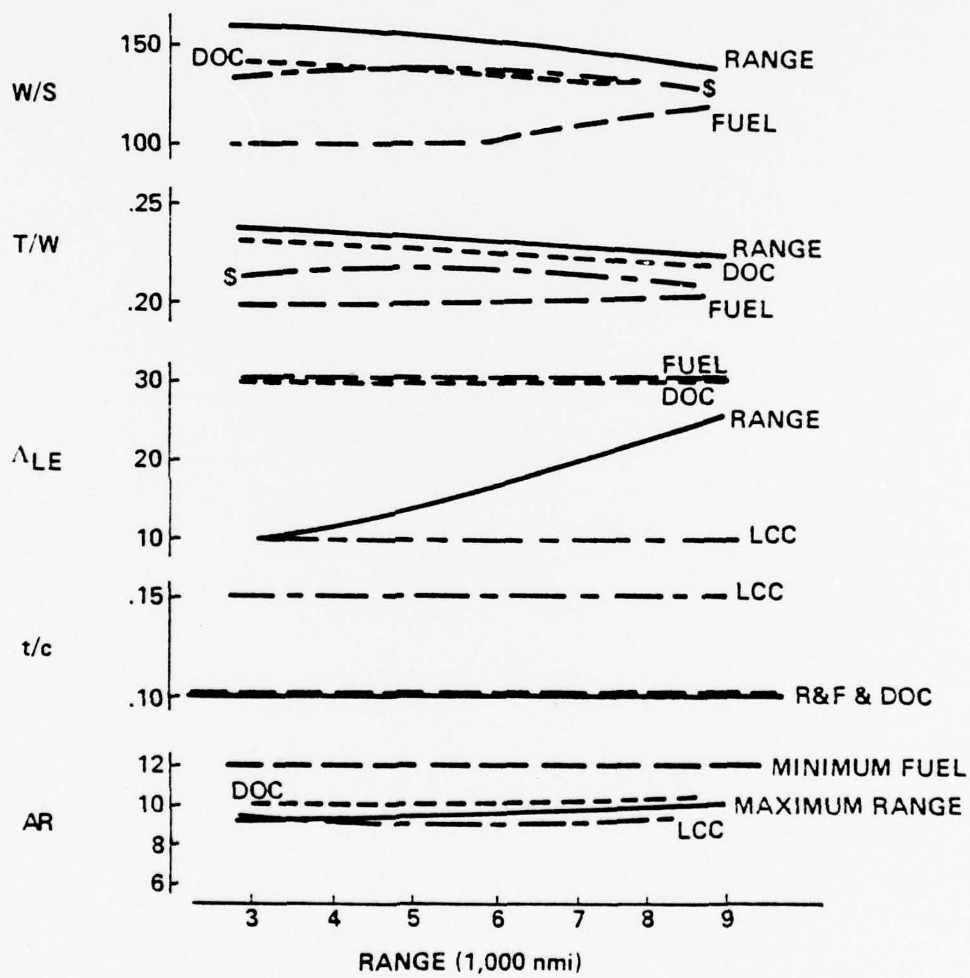

Figure 1. Planform Characteristics

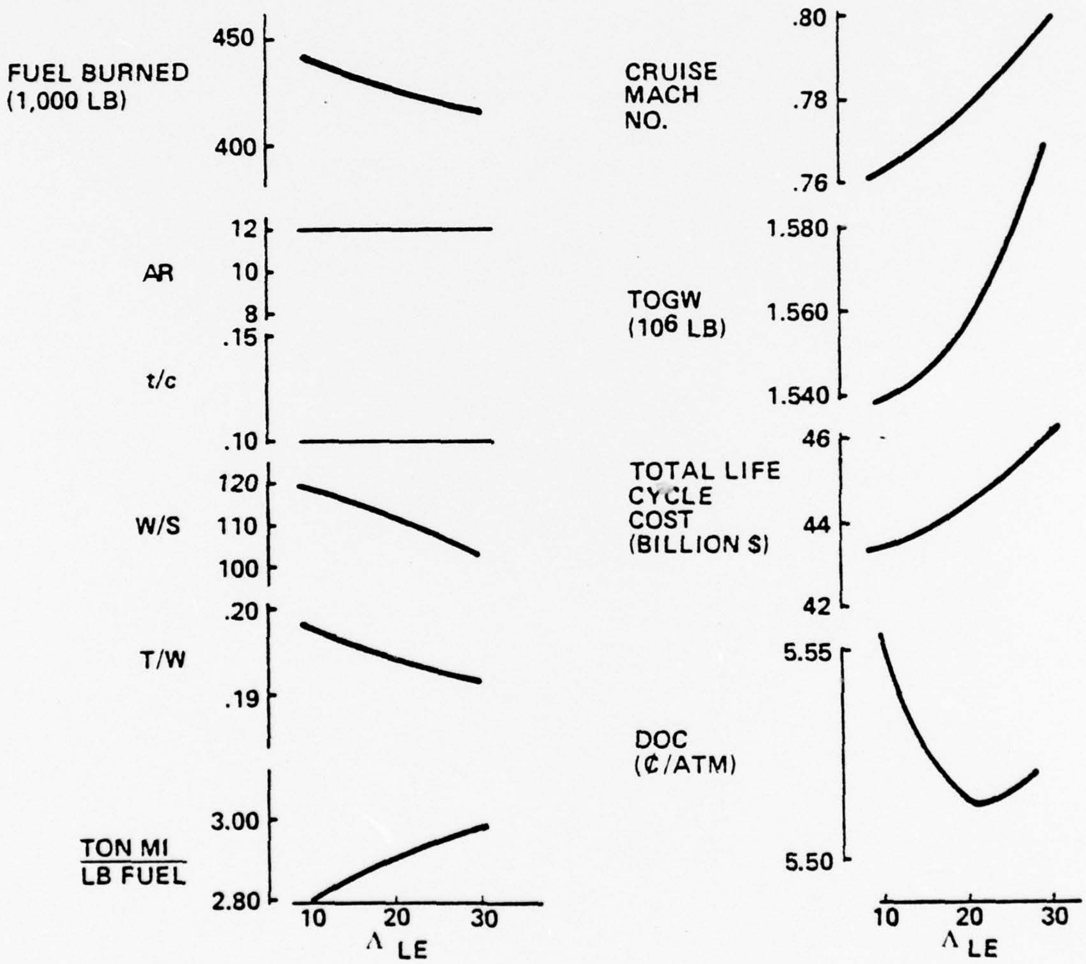

Figure 2. Sweep Sensitivity

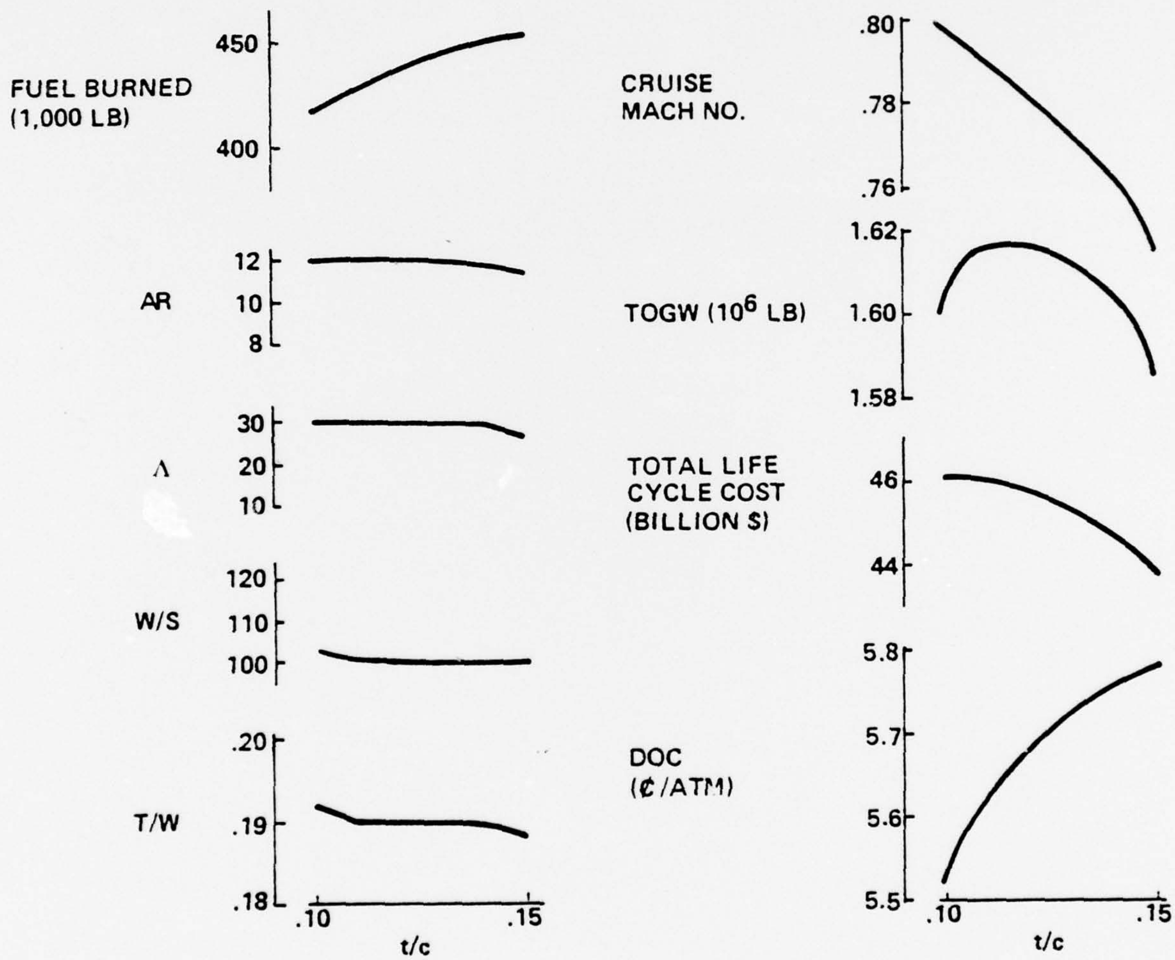

Figure 3. Thickness Sensitivity

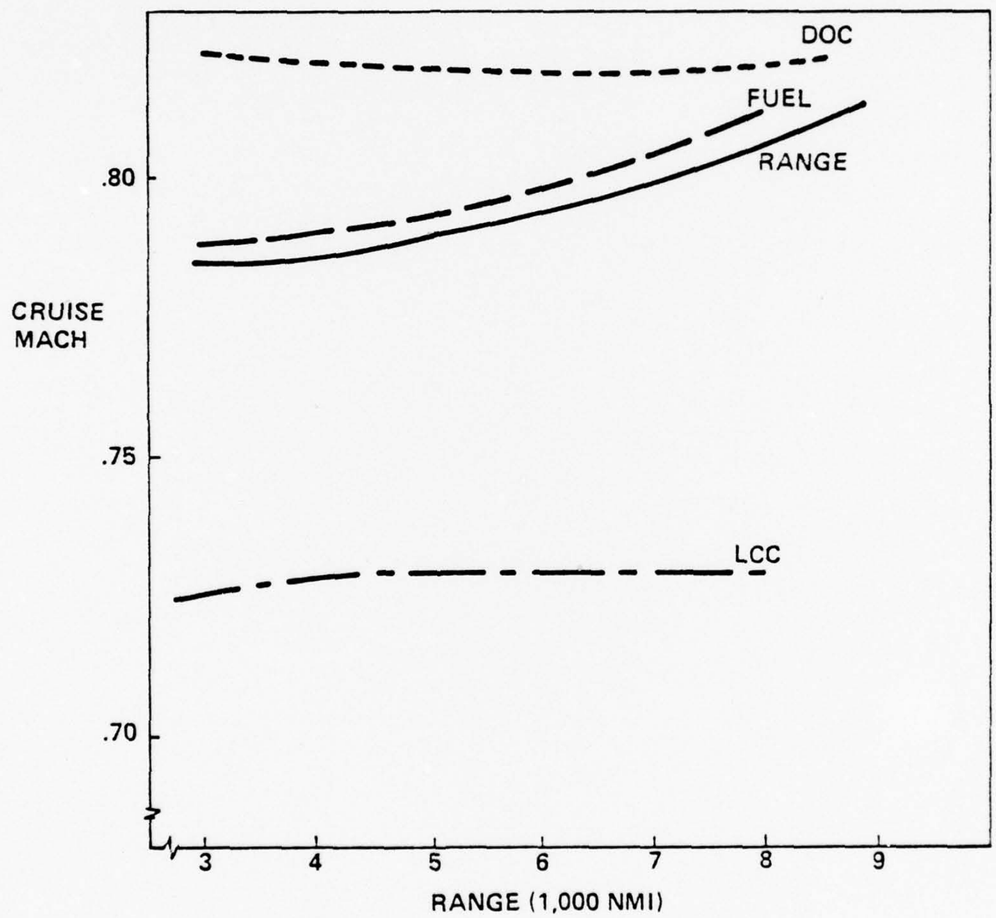

Figure 4. Effect of Cruise Mach Number

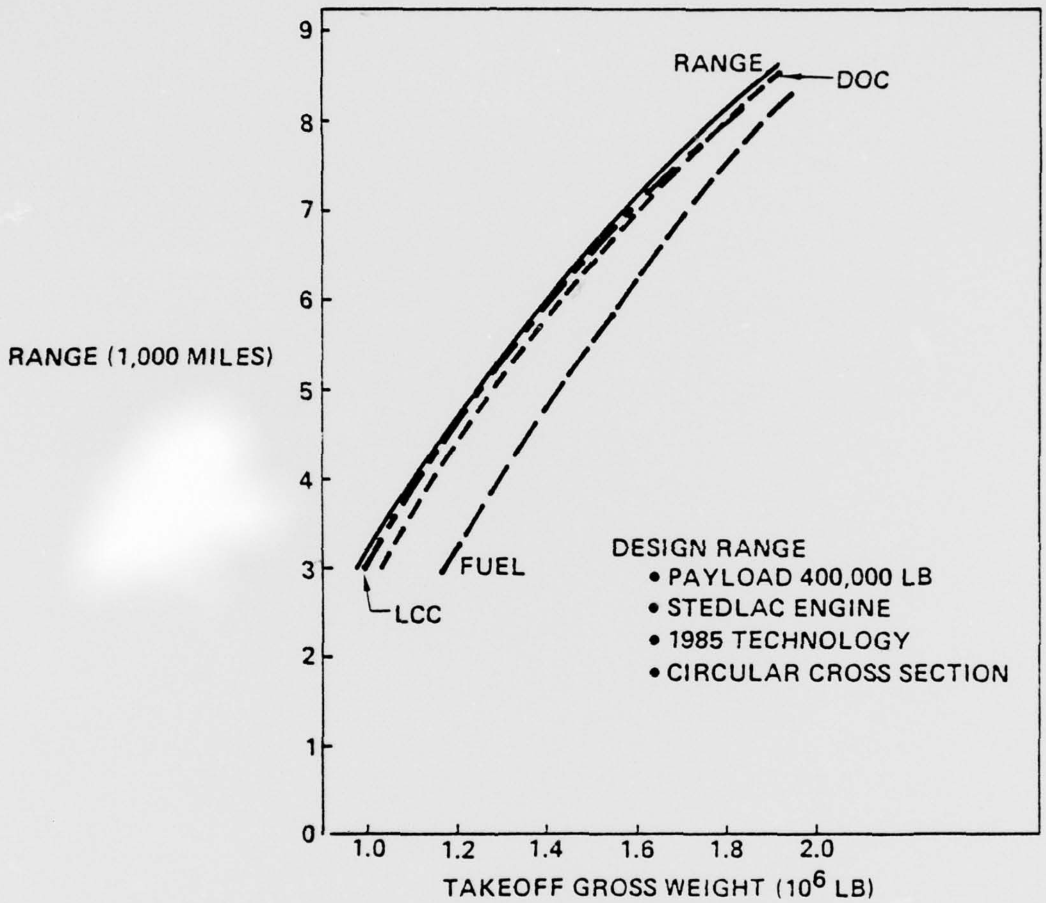

Figure 5. Range Versus TOGW

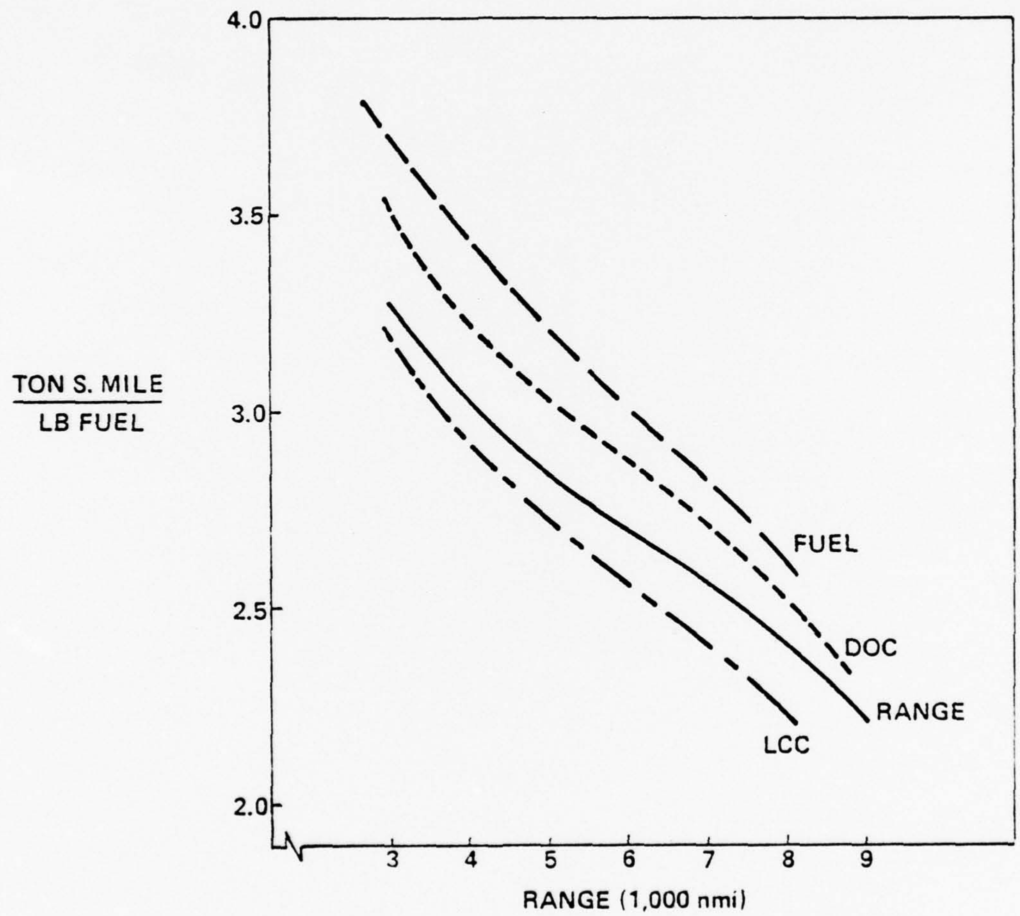

Figure 6. Fuel Efficiency

● 1985 TECHNOLOGY
● 400,000 LB PAYLOAD
● STEDLAC ENGINE

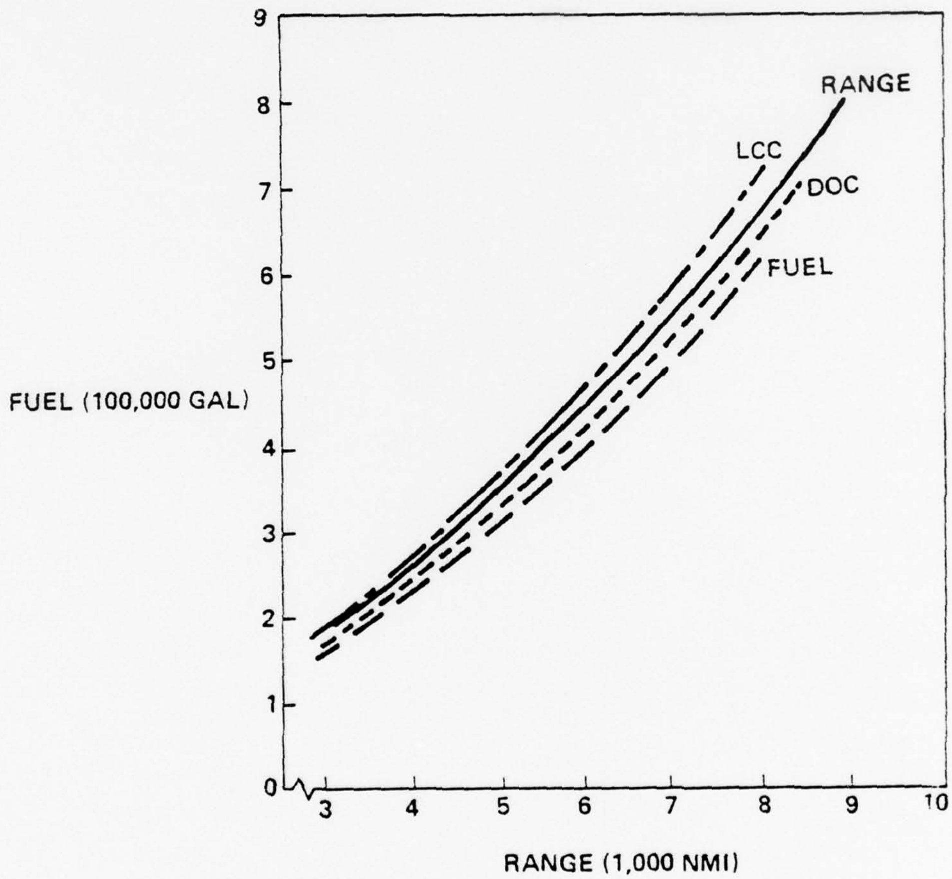

Figure 7. Fuel Burn

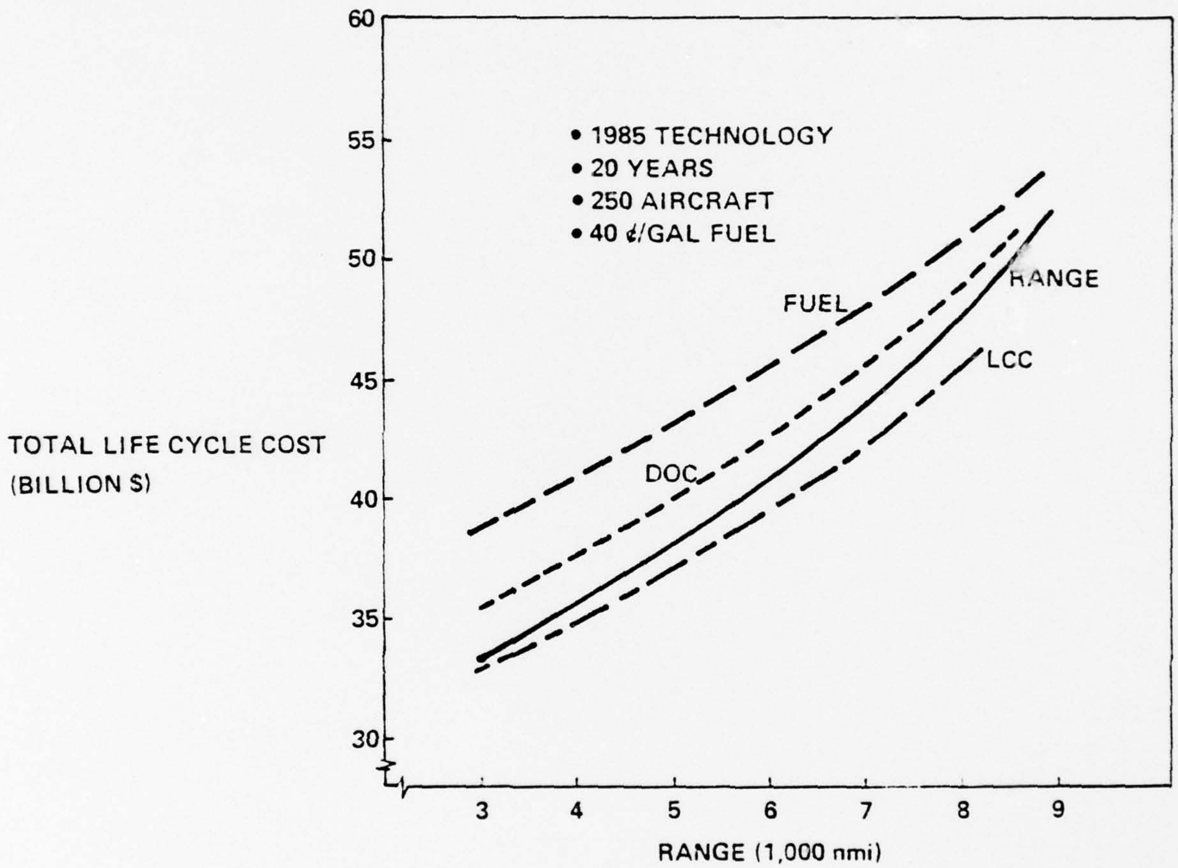

Figure 8. Life Cycle Cost (LCC)

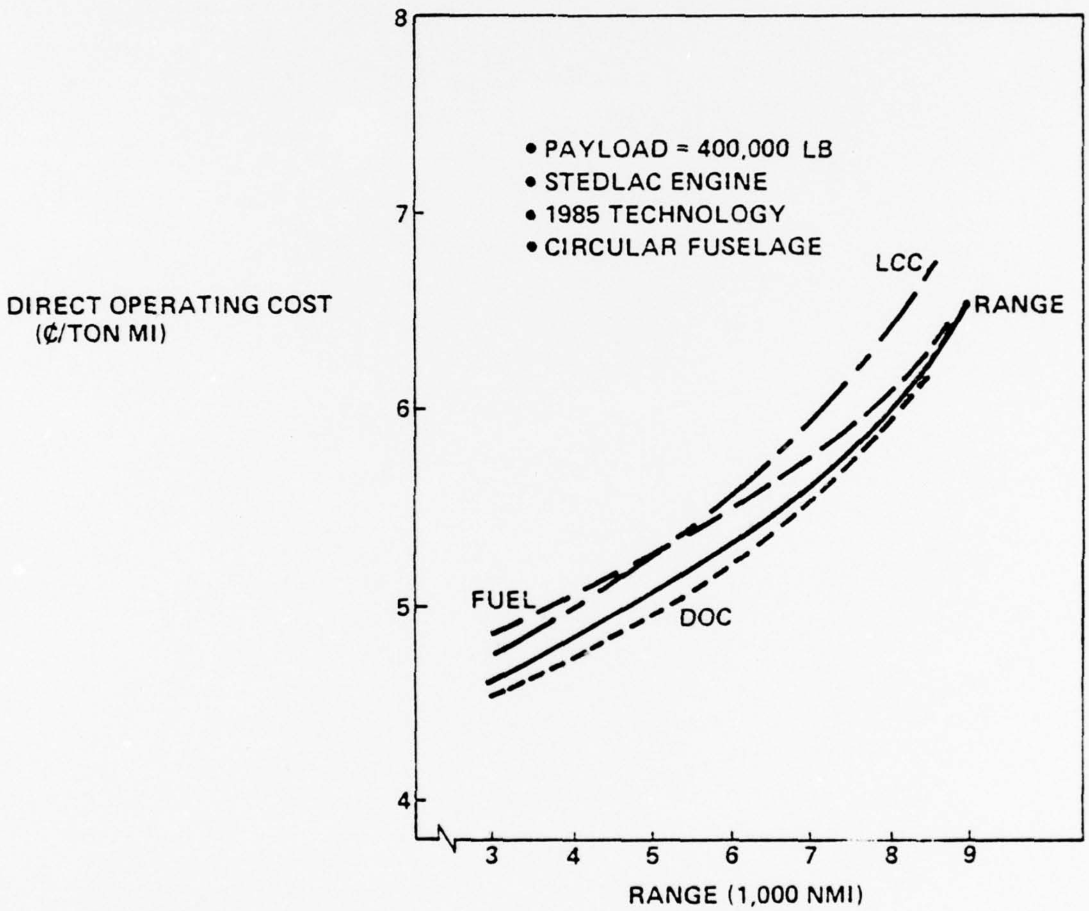

Figure 9. Direct Operating Cost (DOC)

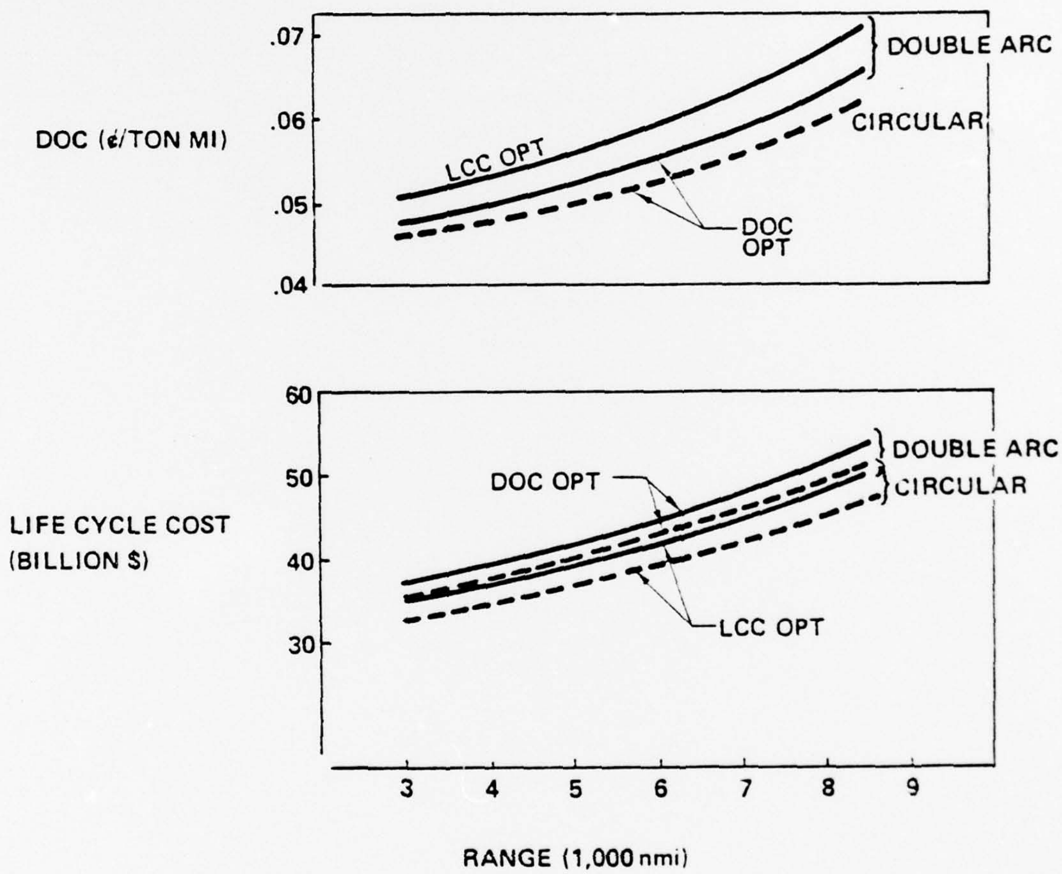

Figure 10. Cost Sensitivity

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APPENDIX E

Technology Assessment

Aerodynamics

Propulsion

Structures

Mechanical Electrical Systems

APPENDIX E

TECHNOLOGY ASSESSMENT ADVANCED TECHNOLOGY CONCEPT DESCRIPTION

1.0 AERODYNAMICS TECHNOLOGY

1.1 Variable Chamber

What It Does: Variable chamber changes wing section camber to allow optimum operation at all phases of the flight envelope which are normally flown "flaps up." This concept would allow an optimum high-speed cruise airfoil to be designed without compromise for "off design" performance such as long range cruise, climb, holding and buffet margin.

Development Status: Extensive analytical studies and wind tunnel tests have been conducted on thin wing combat configurations. Flight tests are currently being planned. Additional work is required to identify and quantify the variable camber payoff for thick wing subsonic designs.

Development Costs: Development costs which will involve large scale testing at high Reynolds number as well as manufacturing developments on the order of $10M.

Development Time Scale: Variable camber designs could be operational by 1985.

Concept Applicability/Limitations: Initial development of the variable camber concept has been for application to thin wing, highly maneuverable

combat aircraft. Applications to large transport aircraft with moderate to low wing loadings are forseen which would considerably simplify high lift systems together with climbout L/D benefits.

Technical Payoff: Variable camber may improve "off design" lift to drag ratio by 10%.

1.2 Laminar Flow Control

What it Does: Laminary flow control greatly reduces friction drag by maintaining a laminar boundary layer through sucking off low energy air close to the surface through holes, slots, or porous skin.

Development Status: The technical feasibility of LFC has been demonstrated in the research carried out by Dr. W. Pfenninger and his associates in the X-21 flight program. The economic feasibility has not been as well established and depends upon, 1) the weight penalty for a practical bleed slot, duct configuration, and pumping system, 2) maintenance and operational costs, including effects of utilization differences, if any, associated with the LFC system, and 3) initial airplane cost increment associated with LFC.

Development Costs: At the conclusion of the X-21 program, a number of problems existed that required additional understanding for the successful application of LFC to transport aircraft. Problems which still exist today (e.g., LE instability of BL, allowable roughness, steps and gaps, humidity

effects, high lift compatibility, construction techniques, etc.) must be resolved before a practical LFC oriented configuration concept can become a reality. It is estimated that such a R&D program would require between $100M and $200M.

Development Time Scale: A LFC airplane could be operational by 1990.

Concept Applicability/Limitations: LFC has the greatest potential performance benefit for long-range or high endurance airplanes, and in particular, freighter type aircraft with "global" range requirements.

Technical Payoff: LFC on a long range airplane can result in a net aerodynamic efficiency, ML/D increase of 30%.

1.3 Advanced High Speed Airfoils

What it Does: An advanced high speed airfoil permits increases in cruise speed without sacrificing L/D. At moderate subsonic Mach numbers, the relatively large variation in upper surface curvature on a conventional airfoil produces an area of supersonic flow that is terminated by a strong shock wave This shock produces a pressure drag associated directly with shock strength. On the other hand the high speed airfoil by virtue of its reduced upper surface curvature produces a partly isentropic recompression of the local supersonic flow on the airfoil surface. As a result of this nearly ideal recompression, the terminating shock wave can be kept weak until significantly higher free stream Mach numbers are reached.

Development Status: Analytical predictions and wind tunnel data which confirm the predicted gains are available. Also, available is some flight test data. Additional analytical work is required leading to a full three-dimensional transonic analysis method. Careful tailoring for each spanwise location to eliminate 3-D effects is required. The resulting method will have to be verified by both wind tunnel and actual flight tests.

Development Costs: To realize the full potential of advanced airfoil technology, an anticipated development cost of $10M is required.

Development Time Scale: High speed airfoils can be developed by 1990.

Concept Applicability/Limitations: High speed airfoils will be most applicable to high subsonic/transonic long range aircraft.

Technical Payoff: High speed airfoil designs can increase aerodynamic efficiency, ML/D, by 10%.

1.4 Natural Laminar Flow

What it Does: Natural laminar flow reduces friction drag by delaying boundary layer transition. The low drag of laminar flow airfoils is achieved by designing for long stretches of laminar boundary layer by moving the point of maximum thickness and, therefore, the point of minimum pressure a considerable distance aft of the leading edge.

Development Status: The concept of natural laminar flow has been used and proven on low Reynolds number applications such as sail planes and up to a Reynolds number of 18 million on the P-63 King Cobra flight tests. Analytical work is in progress to design high-speed natural laminar flow airfoils. Additional analytical design work and flight test verification is required along with studies to establish smoothness and waviness criteria along with the associated manufacturing costs.

Development Costs: Development of manufacturing and operational techniques are the primary drivers (e.g., surface waviness and roughness, gaps, contamination). An estimated $5M is required including technical developments.

Concept Applicability/Limitations: Since natural laminar flow airplanes will have low sweep to avoid cross flow instability, as well as lower critical Mach number, cruise speeds will be relatively low (7-.78). This will tend to limit application to those cases where fuel burned is the primary figure of merit such as cargo or high endurance patrol aircraft.

Technical Payoff: Natural laminar flow airfoil design will increase aerodynamic efficiency, ML/D by 7%.

1.5 Compliant Skin

What it Does: Compliant skin reduces turbulent skin friction drag by providing a compliant wall which accommodates pressure fluctuations in the boundary layer and reduces shear stress.

Development Status: Although turbulent skin friction reductions have been achieved in wind tunnel tests of flat panels the mechanism of drag reduction are not fully understood. Further research into the mechanism of drag reduction, both theoretical and test, is required. Tests are also required on representative airplane components as well as verification of drag reductions in the aircraft flight environment. Research into the characteristics of low modulus materials is required to develop materials with the desired characteristics and durability. Studies will have to be done to determine the impact on manufacturing and maintenance and to develop methods to guide application of the compliant skin.

Development Costs: Somewhere between $10M and $100M - difficult to scope since "breakthrough" in understanding and material technology is required.

Development Time Scale: Compliant skin designs could be operational by 1990.

Concept Applicability/Limitations: Compliant skin offers the biggest payoff to those designs having a relatively large fuselage.

Technical Payoff: Compliant skin offers potentially the same improvement as body boundary layer control, 4% improvement in ML/D.

1.6 Body Boundary Layer Control

What it Does: Body boundary layer control reduces fuselage drag by the use of low energy air injection through a series of a ring slots around the front of the fuselage together with aft-body suction to prohibit separation and reduce the body profile drag. The low energy air required for the slot injection system could be obtained from an aft-body suction system or from a wing-tail laminar flow control system.

Development Status: Turbulent skin friction reductions have been obtained experimentally and these results have been consistent with analytical projections. Additional work includes, 1) research into the drag reductions mechanism, 2) tests to investigate configuration variation effects, 3) studies to determine manufacturing and maintenance impact, and, verification of drag reductions in flight tests.

Development Costs: Development of body BLC appears to be lower risk and more predictable than compliant skin developments to achieve the same payoff - hence projected development costs are the $10M-$20M range.

Development Time Scales: This concept could be developed by 1990.

Concept Applicability/Limitations: Body boundary layer control will have the greatest payoff for large payload cargo airplanes where the body is a significant portion of the parasite drag.

Technical Payoff: Body boundary layer control can improve aerodynamic efficiency ML/D by 4%.

1.7 High Aspect Ratio, Strut Braced Wings

What it Does: High aspect ratio, braced wings offer a means for increasing the wing span over that of an equal weight cantilever wing providing a direct reduction in induced drag.

Development Status: The ultimate development of high aspect ratio strut braced wings depends primarily on the ability to construct a high-modulus composite strut. Detailed structural analysis and testing of strut braced wings applied to a large subsonic transport on cargo aircraft is required. Aerodynamic test/development of strut interference effects at transonic Mach numbers needs to be determined.

Development Costs: Analytical and test developments are estimated at $2M.

Development Time Scale: Strut braced wing aircraft could be operational by 1985.

Concept Applicability/Limitations: Strut braced wings will be most applicable to large cargo designs and other designs where fuel is the primary figure of merit.

Technical Payoff: Strut braced wings offer the potential of a 12% increase in lift to drag ratio.

1.8 Wing Tip Fins/Split Wing Tips

What it Does: Wing tip fins or split wing tips reduce induced drag by altering the lift distribution and modifying the trailing edge vortices. Increased wing lift results in a more efficient lifting surface; that is for a given total lift, a lower angle of incidence is required which directly reduces the wing-induced drag. An important secondary effect is the reduction of wake vorticity intensity.

Development Status: The use of wing tip fins to reduce drag of transport aircraft has received considerable renewed interest. A substantial background of theoretical and more recently experimental data concerning the aerodynamic characteritics of tip fins has been generated. Boeing has recently completed a study for the Air Force Flight Dynamics Laboratory that included detailed structural design and analyses of tip fins applied to the KC-135 and the C-141 military aircraft. A joint USAF/NASA/Boeing design flight test program is currently being planned for the KC-135.

Development Costs: No further development costs are anticipated in addition to funding already committed.

Development Time Scale: Wing tip fin designs could be operational by 1980.

Concept/Applicability/Limitations: This concept would be most beneficial for span limited designs. Greater drag reduction could be achieved by a simple span extension for new designs.

Technical Payoff: Wing tip fins and split wing tips have the potential to improve aerodynamic efficiency, ML/D, by 6 to 8% for a +1% increase in OEW, when considered as an "add-on."

1.9 Advanced Aerodynamic Design Methodology

What it Does: Advanced aerodynamic design methodology reduces parasite drag and increases cruise Mach number through the sophisticated integration and tailoring of the wing-body, the wing-nacelle-strut, and the off-body-empennage. For example proper wing-body contouring can lead to 1) a reduction of wing-body interference drag, 2) a reduction or even elimination of drag-producing shock wave formation on the upper surface of the inboard wing found on current airplanes, 3) an improvement in L/D and, 4) capability to cruise at near sonic speeds.

Development Status: Analytical methods along with a broad data base are available to accomplish advanced aerodynamic designs. The main unresolved problem is the relationship between manufacturing cost and the overall performance benefit. This must be evaluated on each configuration concept individually.

Development Cost: None. The tools are in hand.

Development Time Scales: Methods in hand can be applied immediately to 1980-1985 IOC designs.

Concept Applicability: These concepts will be most useful applied to the design of high speed (subsonic), long range transport aircraft.

Technical Payoff: Advanced aerodynamic design methods can reduce airplane drag by upwards from 3%.

2.0 Propulsion Technology

2.1 Pre-Cooler

What it Does: A turbofan engine can utilize a pre-cooler to lower the temperature of the compressor discharge air (which is used for turbine cooling) by exchanging heat with the fan discharge air. This process can reduce the amount of cooling flow required to maintain a constant turbine metal temperature, thereby improving cycle efficiency and SFC.

Development Status: Presently, there are no existing engines which make use of the pre-cooler cycle due to the heat exchanger's complexities and the increased engine weight. All engine and airframe manufacturer work dealing with this type of engine cycle is analytical to date.

Development Costs: The cost of developing a lightweight and efficient heat exchanger integration with an engine and developmental costs would be on the order of $20M for 1990 IOC.

Concept Applicability/Limitations: When advanced technology engine cycles utilizing improved component aerodynamics and advanced hot section materials and cooling are considered, significant gains due to pre-cooling are not achieved. This is due to the fact that cooling air requirements of the advanced engine cycles have already been reduced by the use of improved cooling and materials technology.

Technical Payoff: Compared to the current technology engines, SFC improvements of approximately 6% can be achieved by the use of pre-cooling in conjunction with increased overall pressure ratio. However, for the advanced technology engine cycles, SFC gains due to pre-cooling are negligible since cooling flow requirements have already been minimized.

2.2 Turbofan with Regenerator

What it Does: The regenerator is a heat exchanger which uses the hot exhaust gases leaving the turbine to pre-heat the relatively cool air leaving the compressor prior to its entry into the combustion chamber. For a given combustor exist temperature, the required heat addition from combustion of fuel is reduced, with a corresponding SFC improvement. Offsetting this improvement is the additional bulk, weight and complexity of the regenerator, and the corresponding increase in maintenance costs.

Design studies have shown that the volume and weight penalties of regenerative engines are minimized by the use of a rotary-type heat exchanger, and subsequent studies were based on this approach.

Development Status: Other than adaptation of designs of automotive gas turbine and some analytical work, development of regenerator systems for advanced airplane propulsion engines has been minimal.

Development Costs: Incorporation of this concept into an advanced airplane engine would require a major development effort by engine and airframe manufacturers. Development costs would be in the $200 plus million range, spread over a 5 to 10 year period.

Concept Applicability/Limitations: Analytical studies of the regenerative engine have shown a potential for substantial gains in SFC over the conventional engine. A heat exchange with an efficiency of 60% and 7-9% pressure drop is the break-even point for SFC. Any lower pressure losses or higher exchanger efficiencies yields substantial SFC gains over the conventional engine.

The regenerative engine has SFC improvement characteristics which are minimized with overall pressure ratios, OPR, in the range 5 to 10. This range is substantially lower than conventional gas turbine cycles which can have OPR ranges of up to 40. The incorporation of the regenerator also increases the installed engine weight by 30 - 70%. It has been found that the higher overall pressure ratios, higher allowable metal temperatures and high component efficiencies of advanced conventional cycles result in SFC benefits comparable to the best advanced technology cycle with regeneration.

Technology Payoff: Because of the minimal improvement in SFC relative to conventional cycles incorporating advanced technology, the substantial weight increase (30 to 70%) of the regenerative engines, and anticipated increase in maintenance costs no overall improvement in airplane performance is likely, enough to warrant development fund expenditure.

2.3 Advanced Component Aerodynamics

What it Does: Through improved analytical aerodynamic and mechanical design techniques, significant improvements in SFC, and small reductions in engine weight, can be obtained from conventional turbofan configurations. These improvements result from increased component load factors and efficiencies, resulting from improved blade tip and intra-blade row analytical design procedures, and the use of composite structure.

Development Status: Turbofan studies show that fan surge margin is generally controlled by blade tip flow phenomena and research into the areas of tip clearance control, blade alignment with the end wall boundary layer and tip treatment techniques could significantly improve surge margin at a given loading level. This improvement could then be traded to achieve high loading levels at present surge margins. It is conceivable that within 10 years, fan duct loading coefficients of approximately 0.6 (20% increase) could be achieved without a sacrifice in surge margin. Gains in fan efficiency of approximately 3% at high wheel speeds should be attainable. This efficiency gain can be obtained through use of intra-blade rwo analysis, elimination of part span shrouds through composite structural designs and

through tip clearance control. With the intra-blade row analysis, designers will be able to shape the blade to control and reduce the strength of the shocks within the blade passage. Also, if part span shrouds are needed, the blade can bè locally shaped to better account for the effects of the shroud and thus reduce the losses associated with a shroud.

Compressor studies show that tip speeds may be expected to increase 10% from current values around 1200 ft/sec to approximately 1350 ft/sec within the next ten years. This expected increase in tip speed will improve the loading of the compressors. Studies show that efficiency improvements in compressors will be more difficult to achieve than in fans over the next ten years because the aerodynamics of compressors are predominately subsonic and reasonably well understood, while fans have large shock losses which may be minimized by improved analytical design techniques. However, there are areas of development which should increase efficiency by 1 to 2%, such as proper alignment of the blades with the endwall boundary layer to reduce losses in this region, improved tip clearances and seal leakages to reduce overall compressor losses. Similar improvements in turbine aerodynamic design are anticipated within this time period, resulting in increased loading coefficients (20%) and small efficiency improvements (1%).

<u>Development Costs and Time</u>: To achieve the component aerodynamic improvements discussed above, a ten year development program of analysis and test is required. The continuation of currenly funded APSI/ATEGG program should cover such developments as is augmented by FDL supporting programs.

Concept Applicability/Limitations: The improved component technology resulting from such a development program would be directly applicable to any new engine system, commercial or military.

Technical Payoff: Assessment of the aerodynamic and mechanical design improvements discussed above shows SFC benefits ranging from 7 to 10%, with small reductions in engine weight.

2.4 Advanced Materials, Cooling and Combustor Pattern Factors

What it Does: Advancement in engine hot section development can be put into perspective for the 1980's by considering technology trends for the following area:

1. Turbine blade materials
2. Annular combustors
3. First stage turbine blade cooling

1. Turbine Blade Materials

   A new generation of materials is being developed to satisfy the demand for higher turbine efficiency. Microstructurally aligned eutectic alloys have the potential to be useful as high temperature structural materials since they are stable at temperatures within a few degrees of their melting points.

2. <u>Annular Combustors</u>

General Electric (GE) and Pratt & Whitney (P&WA) show a downward trend in the pattern factor for the combustor. This improvement in pattern factor will permit a decrease in turbine cooling air requirements, while improved materials will allow an increase in the combustor shell temperatures.

3. <u>First Stage Turbine Blade Cooling</u>

Assuming that the usable range of cooling flow per stage lays between 2 and 4%, the cooling effectiveness could increase by an average of 15% within the next 10 years by changing cooling methods from film-impingement convection to transpiration-impingement convection.

<u>Development Status</u>: Studies of the technology advances in the engine hot section materials and cooling indicate a potential combined increase of 300°F in combustor exit temperatures. The directionally solidified eutectic alloys are expected to contribute a 100°F increase; the improvements in combustor pattern factor and cooling effectiveness are expected to yield the remaining 200°F.

<u>Development Costs</u>: If the existing engine cores were to be used in conjunction with the advanced hot sections and cooling flow paths a cost of $10M per year would be required for a 1990 engine certification date.

Technical Payoffs: The technology advances in the engine hot section materials and cooling yield their greatest SFC benefit in engines which utilize overall pressure ratio in the range of 4081, and cruise rotor inlet temperatures with 2500^{o}R range. A 6-8% SFC improvement can be attained with little weight penalty. This performance increase is largely attributable to a reduction in the turbine cooling air requirements.

2.5 Electronic Fuel Controls

What It Does: Currently, most turbofan and turbojet engines incorporate conventional hydro-mechanical control systems, with a mechanical link between the cockpit and engine controller. Electronic fuel control systems provide automatic engine protection and thrust rating control, thereby preventing inadvertent overboost driving takeoff and climb, and minimize the crew workload. Also, the electronic system permits optimization of the engine steady-state and transient performance with a corresponding benefit in cruise SFC and engine response.

Development Status: Design trade studies and hardware developments of electronic fuel control systems are being conducted in conjunction with the engine manufacturers. An integrated propulsion control system has been demonstrated on the F-111 (IPCS) and is being developed for JTDE for demonstration (FADEC) with advanced technology components.

Additional work is required to establish the reliability and durability of electronic fuel control systems in service, so that redundancy requirements and maintenance costs can be established.

Development Time And Costs: Considerable development work has been accomplished and the technology is available to incorporate electronic fuel control systems. Such systems should be available within 5 years at a development costs of $5 million.

Concept Applicability/Limitations: Electronic fuel control systems are applicable to any gas turbine engine installation, military or commercial, fixed or rotary wing.

Technical Payoff. More sophisticated scheduling of engine fuel flow and variable stators and reduction or elimination of engine trim, should give an SFC improvement of 1%. Maintenance costs should be reduced approximately 2%. Other potential benefits include reduced crew workload and improved interfacing with automatic flight control systems.

2.6 Propulsion System & Airframe Structural Integration Program (PANSIP)

What It Does: Propulsion system structural analysis has become increasingly important with the advent of the high-bypass engine and the continued quest for improved specific fuel consumption, engine maintainability, and reliability.

As propulsion systems become larger, the engines tend to become more flexible. The loads transferred through the nacelle and engine mount distort flexible engine cases, resulting in performance degradation. These difficulties have usually been repaired after engine performance deterioration exceeds limit, and can be time-consuming and costly.

The propulsion system and airframe structural integration program (PANSIP) is intended to achieve total propulsion system structural integrity. By appropriate mathematical modeling of the propulsion system, strut and wing structure, the effect of static, dynamic and thermal load environments on engine case deflections and seal and blade tip clearances can be predicted. The frequency and severity of blade tip rubbing, and the loss of engine performance and life resulting from consequent clearance changes can be determined during the design stage before the engine mount system and structural design have been finalized.

This integrated approach to the engine/airframe structural design offers potential SFC improvements by better blade tip clearance control, and reduced deterioration and maintenance costs, particularly for the high cost HPT (high pressure turbine) module.

Development Status: Implementation of PANSIP was commenced in 1973 and specific 1976 objectives are to 1) continue the propulsion system air and gyroscopic loads study, 2) continue the airframe dynamics loads interaction study, and, 3) expand the joint structural dynamics programs with the engine companies to encompass the effect of airplane loads on TSFC deterioration.

Since the propulsion system for the 1990 IOC cargo airplane will probably be a very large (>60,000 lbs thrust) high bypass (>7.5) turbofan or turboprop, PANSIP is expected to be directly applicable to the engine/nacelle structural design.

Development Costs And Time: The basic technology and communication lines for PANSIP have been established, but substantial development and testing must be accomplished before accurate definition of propulsion system loads and deflections can be achieved. A five year program is required with a total expenditure on the order of $5M.

Concept Applicability/Limitations: PANSIP is a basic approach to engine/airframe structural integration problems, and is directly applicable to any new jet or propellor powered military or commercial airplane program.

Technical Payoff: An improvement of between 1 and 2% in SFC and maintenance costs have been projected.

2.7 Improved Nacelle Aerodynamics

What It Does: Detailed design of nacelle installations requires accurate prediction of 3-D viscous and inviscid flows to achieve optimal performance with a minimum of testing. Application of advanced flow field prediction procedures to the internal and external flow regimes of a new engine/nacelle installation allows rapid definition of the inlet, nacelle and exhaust geometry that minimizes installed SFC. In addition, the use of 3-D viscous flow procedures enables the complex geometry of the internal exhaust mixer to be optimized through parametric geometry variation: the maximum net thrust, and minimum weight, manufacturing cost, and complexity can be found. This procedure would minimize the expensive parametric testing currently employed in mixer and exhaust system development.

Development Status: Flow field prediction procedures are available to compute 3-D viscous flow within an axisymmetric duct. A refined version of this prediction procedure now under development will compute the flow through a duct of abritrary shape.

Development Costs And Time: The capability required is essentially in hand and no further funding is required for application to next generation vehicles.

Concept Applicability/Limitations: Earlier versions of the 3-D viscous flow analysis have been and are being applied to the design of the internal mixer/suppressor nozzle systems for the 727 A/P. The 3-D viscous analysis can be coupled to a 3-D potential flow analysis and applied to the design of powered lift nozzle installations. The viscous analysis will also be applied to the design of inlet and nozzle duct transitions (e.g., 2-D inlets which transition to round at the compressor face and "D" nozzles for upper surface blowing).

Technical Payoff: For the 1990 IOC cargo system technical payoff in terms of performance is estimated to be approximately 1% SFC improvement. However, use of the analysis for design should eliminate much of the prohibitively expensive parametric testing which has been necessary in the past. The analysis could have a large impact on reducing new propulsion system development costs and reduce the technical risk associated with a new design.

2.8 Advanced Fans and Prop-Fans

What They Do: Improvement of the propulsive efficiency of fan engines is possible by the use of 1) larger, more refined turboprops, 2) geared, variable pitch or variable camber, high bypass ratio shrouded fans (Q-fans), and, 3) high bypass ratio geared prop-fans. Each of these concepts provides the advantage of low specific fuel consumption due to the high propulsive efficiency that results from low slipstream velocity increase through the fan or prop. Each of the concepts attempt to blend the high takeoff thrust of the propeller with the high subsonic cruise capabilities of the turbofan. At 0.8 M.N., the Q fan and propfan operate at high enough efficiency to be of interest, while the turbo-prop is restricted to about 0.65 M.N.

The propfan typically uses eight high speed blades and has a bypass ratio of approximately 50. The shrouded Q-fan uses bypass ratios from 10-20. Engines with BPR's greater than 8 usually required a gearbox in order to provide reasonable fan tip speeds while still maintaining high rotor speed for efficient turbine operation. These high BPR, low pressure ratio (1.45) devices have blades which are compatible with various pitch designs, providing the tip speeds are restricted to approximately 1100 fps. The actuating mechanisms require hub/tip ratios $\geq$ .44. The combination of variable pitch and variable nozzle area minimizes TSFC over a relatively large portion of the flight envelope.

Development Status: Full-scale Q-fans have been ground and tunnel tested with promising results. The current Hamilton-Standard Q-fan tests use a 62 inch fan and design pressure ratio limited to 1.18. Reverse thrust levels and the time required to obtain reverse thrust are excellent. Hamilton-Standard is currently testing full-scale prop-fans under NASA contract. Hamilton-Standard prop-fan models have been wind tunnel tested to M = .8, 35,000' with a net installed propeller efficiency of 0.80 (as compared to 0.62 for turbofans).

The basic thermodynamic and mechanical design programs that have been developed for turbojets and turbofan core engines apply equally to the systems under consideration and only require adapting specified propeller characteristics. The latter, including propeller and gear box weights for both prop-fans and propellers are currently furnished by Hamilton-Standard in the U.S., and Dowty-Rotol in the U.K. Boeing engine/airplane programs allow performance trades to be made with account for propeller tip speed, disc loading, propeller diameter, core engine pressure ratio and turbine temperature. The primary nozzle pressure ratio can be varied to optimize the thrust split between the propeller and core engine.

Computer studies which integrate the engine, airplane and mission requirements for turboprops, Q-fan and prop-fans, are sufficiently accurate to allow preliminary selection of optimum engine cycles and propeller or fan sizes.

Development Costs: Advanced fans and prop-fans will require a major development program involving engine and airframe manufacturers and government support. It is expected that $5-10 million would be required per year over a ten year interval to realize the full potential of prop-fans in the 1990 time period.

Technical Payoff: There is evidence that the cruise efficiency of the prop-fan is higher than that of a conventional turbofan up to a cruise Mach number of at least 0.80. The cruise efficiency of the Q-fan is less than that of a prop-fan but still higher than the turbofan up to cruise Mach number of .8. Besides TSFC improvements below M = .8, the noise of the Q-fan is less than the turbofan due to relatively low tip speed, low pressure ratio and fewer blades. An appreciation for size and core horsepower requirements can be obtained by comparing a conventional turbofan (BPR 5:1) and a large Q-fan (BPR 20:1). For example, when sized to produce equivalent takeoff thrust, the Q-fan has a 40% larger cross-sectional area but requires a core producing only 1/2 the power required for the turbofan. The advantage of low TSFC is counterbalanced by configuration problems due to large fan size. Other concerns are blade failure, reliability, maintenance, and costs. Though these concerns are real, substantial improvement in the proposed systems relative to the earlier turbo-props should be recognized.

According to assessments by Hamilton-Standard, the potential payoff for using prop-fans rather than conventional turbofans on a 1990, M = .8 cargo plane include, 1) 15-20% lower TSFC at cruise, 2) 25% reduction in TSFC at slower speeds, 3) 20% better climb performance, 4) 15 PND less than FAR 36 allowed levels at takeoff powers, 5) faster thrust response, and, 6) simply more effective reverse thrust. Negative factors include increased engine weight (50% uninstalled) and potentially higher maintenance costs relative to a conventional turbofan.

3.0 STRUCTURES TECHNOLOGY

3.1 Technology Item: Active Controls Technology

Augmented Stability and Integrated Controls (maneuver and gust load control, fatigue rate reduction, and flutter mode control).

What It Does: Augmented Stability reduces or eliminates the need for inherent static or dynamic stability resulting in reduced empennage size and more favorable airplane balance. Maneuver load control redistributes wing lift during maneuvering flight in a way that shifts the center of lift inboard resulting in reduced wing root bending moments. Gust load control reduces airframe peak transient loads resulting from large gusts. It includes both rigid and flexible airplane response. Fatigue rate reduction is a technique for reducing the fatigue rate by using active controls to reduce amplitude and/or number of transient bending cycles due to continuous turbulence. Flutter mode suppression is any technique for actively damping flutter modes using aerodynamic surfaces. These items improve performance and/or reduce structural airframe weight.

Development Status And Projection: The use of active controls has been theoretically analyzed. All have been mechanized and verified by flight test on military aircraft. Fly by wire (FBW) systems, a necessary requirement for advancing active controls technology has recently been demonstrated on the F-16. Necessary elements under development are FBW digital FCS with built-in test equipment (BITE). Yet to be accomplished are integrated wing controls, development of an integrated interdisciplinary analysis capability and the development of system identification techniques to a routine basis.

Development Costs: The total research cost for active controls technology is estimated at $8 million broken down as follows: Integrated interdisciplinary analysis capability at $4 million; system identification at $1 million; digital flight control system design philosophy at $1 million and an Integrated Controls feasibility design study at $2 million.

Development Time Scale: All of the above items could be accomplished by 1985.

Concept Applicability/Limitations: All of the above items are applicable but must be applied at the earliest design phase in the configuration development to be fully effective. Flutter mode control is a flight critical item that is only effective where considerable weight is required for flutter stability.

Technical Payoff: The magnitude of the payoff is configuration sensitive. Studies and development programs to date have shown the following:

Augmented Stability - -1.5% OEW + improved performance;
Gust Load Control - -1% OEW + ride quality;
Fatigue Rate Reduction - -3% wing box weight + ride quality;
Maneuver Load Control - -4% wing box weight;
Flutter Mode Control - configuration dependent.

3.2 Technology Item: Materials

Improved Aluminum alloys, improved steel and titanium alloys, composite primary structure, powder metallurgy.

What It Does: Improved alluminum alloys provide higher strengths and higher toughness by using alloys with low silicon and iron content. Fatigue life and stress corrosion resistance at the higher stress levels is maintained at current levels. Improved steel and titanium alloys provide increased resistance to stress corrosion and higher toughness, while maintaining current strengths. In the case of titanium, lower oxygen content results in higher toughness in thick sections, as well as more formable sheet alloys. Composite primary structure provides increases in strength and stiffness over metallic structure. Power metallurgy (PM) aluminum alloys offer increases in strength, fatigue life, fracture toughness, and corrosion protection.

Development Status and Projection: New aluminum alloy development began in 1975. New high temperature titanium alloys are being developed. Composite primary structure currently exists in the horizontal stabilizer of new military fighters. A portion of the Lockheed L-1011 vertical fin is being built from composites for airline evaluation. Widespread usage of composites in the primary structure of large transports will require extensive development of design, analysis, and manufacturing methods. Small PM aluminum extrusions have been produced on a pilot plant basis. Major new facilities must be developed for full-scale production.

Development Cost: New aluminum alloy development will cost $1.5 million. Composite primary structure will cost $150 to $300 million to develop. Powder metallurgy aluminum alloys will get $2 - $4 million to develop. New facilities will be required at two aluminum suppliers.

Development Time Scale. Production status of high purity aluminum alloys is expected in 1979. Production status of composite primary structure for large transports is not expected until 1990, or later. Production status of power metallurgy could be attained in 1990.

Concept Applicability/Limitations: Improved aluminum alloys will be used in thick plate, bar, extrusion, and maybe in thin sheet. Hence the highly loaded wing box, and portions of the body will use these alloys. The pressure critical portion of the body may not use these alloys, since skin gages are thin and the benefits would be smaller. New titanium alloys

will be used in engine pylons, and large structural fittings, where they will replace steel. Steel alloys are being developed in plate and forgings for primary structure application. Composite primary structure can be used throughout the airframe, either as thick laminated panels, or as honeycomb panels. Special attention to lightning strike, moisture penetration, electrical continuity, rain erosion, hail strike, and electromagnetic pulse from atomic weapons is required for composite structure. Powder metallurgy will first be used in aluminum forgings and extrusions, with plate and sheet developed last.

Technical Payoff: Improved aluminum alloys are expected to result in a 5% reduction in the weight of the wing box. High temperature titanium alloys will reduce the weight of engine support fittings by 40%. Composite primary structure will be 15% to 25% lighter than current aluminum structure. PM aluminum structure will be 8% to 10% lighter than current aluminum structure.

3.3 Technology Item: Structural Arrangement

Metal-to-Metal Bonding, Aluminum Honeycomb Primary Structure, Advanced Skin-Stringer Body Structure, Windshield and Cockpit Design.

What It Does: Metal-to-metal bonding eliminates the weight and cost of riveting, and results in a weight saving in strength critical primary structure. Aluminum honeycomb eliminates panel stiffeners, and allows an increase in body frame spacing, thus reducing parts. An advanced skin-

stringer body structure, using zee stringers and a special extruded frame, provides weight and cost reductions. The use of a circular, or double lobe, cross section for the cockpit allows use of a single curvature windshield, that carrys cabin pressure in hoop tension, resulting in lighter body structure and lower life cycle costs for the airframe.

Development Status And Projection: Extensive use of metal-to-metal bonding exists at Boeing using sheet and doublers, but no structural bonding of stiffeners has been developed. Large honeycomb body panels have been built for a test section of the 747, but static, fatigue, and corrosion tests remain to be completed. No development tests have been conducted at Boeing on zee stiffened body panels, but their use represents the application of state of the art knowledge. Curved windshields, carrying internal pressure load in hoop tension, are in use on several military aircraft. Problems of reliability, manufacturing fit-up, and cost remain to be solved.

Development Costs: It is estimated that the development of adhesive bonding for stiffened panels will cost $1 - $3 million, while aluminum honeycomb will cost $1 - $15 million depending on test component size. Advanced skin-stringer body structure will cost $.5 million to conduct panel compression and shear strength tests, stringer joint fatigue tests, sonic tests, and frame strength tests. The development of high reliability curved windshields will cost $.2 to $1.5 million.

Development Time Scale: All of the structural arrangements discussed can be developed by 1980, except aluminum honeycomb, which will not achieve production status until 1985.

Concept Applicability/Limitations: Metal-to-metal bonding of stiffeners if possible wherever straight line elements exist in the wing, body, or empennage, such as single curvature skin panels. Double curvature skin panels require more expensive tooling and result in a higher risk of stringer delamination. Aluminum honeycomb is competitive, weightwise, in any primary structure where the compression load/inch is below 10000 lbs/inch, except in very lightly loaded body structure, where cabin pressure loads dominate. body panels stiffened by zee stringers may not be adequate in high sonic fatigue areas, where hat stringers provide longer life. Curved windshields will be applicable to all future transports, particularly those that are pressurized.

Technical Payoff: A 5% weight reduction on strength critical structure is expected from metal to metal bonding, while a weight and cost saving is expected from aluminum honeycomb depending on the component. The advanced skin-stringer body will result in a 7% reduction in body weight using riveted construction, and a 12% reduction using bonding. Hoop tension windshields result in lighter window framing and lighter body structure.

3.4 Technology Items: Low Noise Transmission Design of Body Structures

What it Does: The body structure is designed to minimize the transmission of external noise from the engine and boundary layer. This is done by tuning the structural frequencies of skin panels, stringer, and frames. The tuning is accomplished by adjusting the thickness of the skin and the spacing and stiffness of the stringers and frames.

Development Status and Projection: The concept of intrinsic structural tuning has been under development at Boeing for the past three years. Small structural components have been tested in the laboratory, while skin panels have been field tested. Flight testing of damping treatments on a 747 will be completed this year. Future development will determine to what extent this concept is practical on strength designed body structure.

Development Cost: Current development is directed toward skin-stringer-frame body structure. If this results in significant changes to the established geometry of hat stiffened panels, the development cost could be $1 million. If changes are small, the analysis and test cost will be about $.5 million.

Development Time Scale: Production design of low noise transmission skin-stringer structure is expected by 1985, while honeycomb panel and composite panel design would not occur until 1990 - 1995.

Concept Applicability/Limitations: The current design effort applys to skin-stringer body panels. Since skin gage is picked by shear or cabin pressure requirements, and stringer gage by tension or compression load, there may be a range of skin and stringer gages in which tuning is not possible.

Technical Payoff: Structural tuning is expected to reduce internal noise levels by 3 to 6 db. This results in the elimination of lead septum, with a cost and weight reduction.

3.5 Technology Item: Analysis and Design Methods

(1) Stability Analysis of Columns, Plates, and Shells; (2) Optimization Methods for Wing Boxes and Stiffened Cylinders; (3) Damage Tolerance Analysis and Design of Wing Boxes and Pressure Cabins; (4) Pressure Cabin Stress Analysis Methods; (5) Improved Finite Element Analysis Methods; (6) Sonic Fatigue of Flat and Curved Panels.

What it Does: Stability analysis provides new data for the design of wing and body skin panels and body frames. Optimization methods provide design data allowing increases in spacing of wing ribs and body frames. Damage Tolerance Analysis provides data for body pressure loading, while pressure cabin stress analysis provides detail definition of skin stress distribution. Improved finite element analysis is aimed at better prediction of element stresses at ultimate load. New sonic fatigue analysis methods consider the effects of spectrum shape, curvature, hoop tension, and temperature.

Development Status and Projection: In each of these areas there has been various amounts of development. New development will build on previous work in most areas. However, no analysis methods are available for the shear buckling of double curvature panels, while pressure cabin analysis methods give contradictory results.

Development Cost: Cost for all work varies between $1 and $3 million.

Development Time Scale: Development time varies from 4 years for sonic fatigue analysis to 10 years for optimization methods, with all design data available by 1985.

Concept Applicability/Limitations: Wing and body primary structure are affected, with primary emphasis in the body.

Technical Payoff: It is anticipated that stability analysis would provide a 4% reduction in wing and body weight in areas where skin buckling is critical. Optimization methods allow a cost reduction through wider rib and frame spacing, and hence fewer parts. Damage tolerance analysis and pressure cabin analysis may result in a 10% reduction in body skin gage in pressure critical areas. Improved finite element analysis will result in a 2% reduction of primary structure weight. Improved sonic fatigue analysis will result in both cost and weight reductions in sonic critical areas.

3.6 Technology Item: Manufacturing

What it Does: Improved fabrication processes such as N.C. roll forming of aluminum stringers and frames, pultruding of composite shapes, and superplastic forming of titanium provide lower cost details. Improved assembly techniques such as N.C. spar drilling and fastening, advanced faying surface seal methods, and single impact rivet installation, provide lower cost and improved quality assemblies. Computer aided manufacturing (CAM) such as in-line planning and computer controlled sheet metal fabrication centers provide better parts control, reduced inventory cost, and lower manufacturing cost.

Development Status and Projection: N.C. roll forming is currently being used to form 727 a/p stringers. Feasibility of pultruding composite shapes and superplastic forming of titanium have been proven. Improved assembly techniques such as N.C. spar drilling, advanced faying surface sealing and single impact riveting are currently being developed for Boeing Commercial Airplane Computer Aided Manufacturing (CAM). Development efforts are underway by the Air Force Material Laboratory and all aircraft manufacturers.

Development Cost: Development pultruded composite shapes and superplastic forming of titanium will range up to $1 million each. N.C. spar drilling and fastening development costs will be approximately $.5 million; advanced faying surface sealing techniques less than $.5 million. A CAM generated N.C. sheet metal center will cost up to $6 million.

Development Time Scale: Improved fabrication processes and assembly techniques are under continuous development. Advanced faying surface sealing and pultruded composites will be available in 1978; superplastic forming of titanium and N.C. spar drilling and fastening will be available in 1979; a complete N.C. sheetmetal center is expected by 1982.

Concept Applicability/Limitations: Applicable to all airplane components.

Technical Payoff: Reduced cost and improved quality.

4.0 MECHANICAL/ELECTRICAL SYSTEMS TECHNOLOGY

4.1 Secondary Power and Control System Mechanization

Significant advanced technology concepts which have potential payoffs are:

- LOX-JP4 APU emergency power generation systems
- Advanced/Integrated Actuators, IPA
- Actuation Control Sequal Transducers (Digital, Fiber Optics)
- Lightweight, High pressure Hydraulic Systems (LHS) 8000 psi
- Permanent Magnet VSCF Starter/Generator

What it Does: Increased dependency of advanced design aircraft upon fluid and electrical power systems to actuate flight control surfaces and critical mission equipment requires increased availability and continuity of power

from these systems at reduced installation penalty to the aircraft. The LOX-JP4 APU, LHS, and the integrated actuator systems show potential to satisfy these requirements through weight and space reductions and improved availability of power.

The permanent magnet, PM, VSCF Starter/Generator combines the improved efficiency of PM concept for each function into one unit for generation of electrical power and for engine starting.

Development Status: LOX-JP4 emergency APU, lightweight hydraulic systems and integrated actuator packaged systems are in various stages of development under government funded programs. In addition, these concepts are receiving limited evaluation under Boeing IR&D program support. Increased interest and potential support is in evidence for these concept developments from the research laboratories of both the Navy and Air Force. These are low to medium risk development concepts.

The design of the permanent magnet rotor has been successfully completed by G.E. under Air Force contract. Design and test of the generator, is in progress. The complete system, including the VSCF converter, should be in test by next year.

Developmental Costs: Estimated costs to extend these concepts to a meaningful stage of development are:

o	LOX-JP4 emegency system	\$500 to \$1 x 10^6
o	Advanced/Integrated Actuators	\$1, to \$2, x 10^6
o	Digital Flight Computers & Electric Signalling	\$5, to \$10 x 10^6
o	Lightweight Hydraulic System (8000 psi)	\$2 x 10^6
o	VSCF, PM Generator/Engine Starter	\$3 x 10^6

Development Time Scale: To continue concept development to an acceptable level of confidence it is estimated to be:

o	LOX-JP4 Emergency System	2-3 years
o	Advanced/Integrated Actuators	2-3 years
o	Digital Flight Computer & Elect. Signal.	5-7 years
o	Lightweight Hydraulic Systems	2-3 years
o	VSCF, PM Generator/Engine Starter	2-3 years

Concept Applicability/Limitations: The emergency APU, lightweight hydraulic and integrated actuator package system are applicable to the advanced military transport, particularly the LHS and IAP concepts. Integrated actuators become more useful in direct preparation to airplane size. Below 50,000 pound gross weight, there is little to be gained while large transports, the weight saving is substantial.

Practically all aircraft using medium-sized jet engines would benefit from use of the starter/generator concept. Further development would extend the usage to larger and/or smaller engines than the present F-100.

Technical Payoff: Improvement in generator efficiency should be around 5% to 10%, which reduces horsepower extraction from the engine and thus improves performance. Total weight reduction should be around 20 to 30 lbs.

The incorporation of the advanced integration actuator package would save an estimated 700 to 1500 lbs. Additional weight savings of 50 to 100 lbs for the LOX-JP4 emergency systems and 30% of the total hydraulic system weight by use of lightweight (8000 psi) hydraulic systems are possible to the aircraft O.W.E.

4.2 ECS - Avionics Cooling - Advanced Cooling Cycles

What it Does: Current technology transport obtain ventilation, pressurization and avionic cooling flow from engine compressor bleed air with associated airplane performance penalties. New concepts which extract less engine bleed air and provide recirculation flow for ventilation and cooling can significantly reduce operating penalties. One possible new concept uses bleed air for pressurization only coupled with a ram air turbine to provide more effective cooling per pound of ram air with associated lower drag.

Development Status: Air cycle machines are not under development. However, the concept does not require new turbo-machinery technology developments since dual nozzle turbines are in production.

Development Cost: A development program to obtain a test machine and conduct verification tests is estimated to cost $500,000 to $1,000,000.

Development Time Scale: Hardware design, manufacture and test program would require 12 to 18 months.

Concept Applicability/Limitations: Concept is applicable to all airplanes both subsonic and supersonic.

Technical Payoff: Technical payoff would result from reduced engine bleed air and ram air requirements with associated improvements in cruise SFC. A 3% to 4% improvement in airplane SFC may be obtainable.

4.3 Landing Gear System

Significant concepts which could provide technical payoff are:

- Limited slip - closed loop anti-skid system
- Air cushion landing system (ACLS)
- Advanced carbon brakes

What it Does: Limited slip-closed loop anti-skid control system provides more effective braking with associated shorter field lengths and less tire wear than current technology anti-skid systems. This is accomplished in the control system by limiting the wheel slip (%) to values which result in operating on the forward side of the brake force curve with associated lower tire wear and increased side force relative to current anti-skid systems which operated on the back side of the brake force curve.

Air cushion landing systems are currently under development for small low speed aircraft which can operate from rough fields. Potential payoff could be lower weight, lower airfield construction cost and less maintenance cost.

Advanced carbon brakes offer significant weight reduction with equivalent braking performance as present systems.

Development Status: Limited slip-closed loop control systems are being evaluated by Boeing on a bread board brake control analog-hardware simulator. Development time for full scale hardware would be approximately 3 years. Air cushion landing systems are under development on the Jindivik RPV and the Buffalo with flying hardware. Unresolved development problems in ACLS include:

- Runway directional control
- Airplane drag evaluation
- Air trunk flutter
- Inflation - retraction
- Material wear

Air cushion landing systems at present represent very high risk to obtain significant gains.

Carbon brakes are presently in use on several high performance USAF aircraft (e.g., F-15, B-1), and have encountered some operational problems, e.g., oxidation, moisture absorption, wear. These problems impact brake performance and life cycle costs. USAF is actively pursuing programs to resolve these problems. Advanced carbon materials available today appear to solve most of these crucial problems.

Development Costs:

Limited slip brake system	\$500,000
Air cushion land system	\$ 4 + million
Carbon brakes	\$2-3 million

Development Time Scale:

Limited slip brake system	3 years
Air cushion land system	5 years
Carbon brakes	5 years

Concept Applicability/Limitations: Limited slip control concept is applicable to all USAF aircraft and commercial aircraft.

Air cushion landing systems have been applied only to small aircraft with unique landing requirements (water, rough fields).

Carbon brakes are also applicable to all aircraft.

Technical Payoff: Limited slip-anti-skid brakes have a potential reduction in field length of 10% - 25% (for wet and/or icy runways) relative to current technology and approximately 30% reduction in tire and brake maintenance cost due to less wear.

Since air cushion landing systems have not been applied to large transports it is difficult to quantify technical payoffs.

Advanced carbon brakes are significantly lighter than current brakes (33%) which would result in a weight decrement of approximately 2000 lbs. for a large military transport.

TABLE 1. AERODYNAMICS ADVANCED TECHNOLOGY CONCEPTS

TECHNOLOGY CONCEPT	WHAT IT DOES	DEVELOPMENT STATUS	DEVELOP. COST & TIME	TECHNICAL PAYOFF POTENTIAL
Variable Camber Aero. Surfaces	Allows Opt. Camber & Twist at all Flight Conditions	Extensive W-T and Analytical Work Complete. Needs Full Scale Hardware and Flt. Test Dev.	$10M For 1985 IOC	• Simplify Hi-Lift Flap Systems • Improve Off Design L/D ~ 10%
Laminar Flow Control	Reduce Friction Drag Through BL Suction	Feasibility Demo. By X 21 Practical MFG & Operational Problems Not Solved	$100-$200M For 1990-95 IOC	30% Increase in M L/D
Advanced High Speed Airfoils	Approaches Isentropic Recompression On Airfoil Upper Surface	W-T Tests Confirm Analytical Predictions Additional Work Needed For 3-D Effects Leading To Full Scale Test	$10M For 1990 IOC	10% Increase In M L/D If $M \geq 0.8$ Cruise Required
Natural Laminar Flow	Delays Transition To Turbulent By Moving Min. Pressure Pt. AFT On Airfoil	Analytical Work In Infancy. BL Stability Analyses And Flt. Test Verif. Req'd	$5M For 1990 IOC	7% Increase In M L/D For $MS. \leq 0.75$ Cruise Designs
Compliant Skin	Reduces Turbulent Skin Friction Drag By Accomodating Pressure Fluctuations In The BL	Theo. & Test Work Needed to Understand Current Status Inconclusive.	$10-$100M For 1990-95 IOC	4% M L/D Improvement If applied To Fuselage Only
Body Boundary Layer Control	Reduces Turbulent Skin Friction Drag By Low Energy Air Injection	Has Been Demonstrated Experimentally. Needs More Analytical & Test Work. For Understand-ing & Invest. Of MFG and Operational Considerations	$10-$20M For 1990-95 IOC	4% M L/D Improvement If Applied To Fuselage Only
High AR External Braced Wings	Reduced Induced Drag Through Increased Span While Maintaining Structural Efficiency	Detailed Struct. and Aero Analyses Required. Tech Not New But Application Size and Mach Is	$2 M For 1985 IOC	12% Increase In M L/D
Wing Tip Fins	Reduced Induced Drag Through Altered Lift Distribution	Extensive Analytical and W-T Dev. Work Complete. Flight Test Needed (Planned For KC 135)	None (In Add'n To That For 1980 IOC)	6-8% Increase In M L/D For 1% OEW Penalty
Adv. Aero. Design Methods	Reduces Parasite Drag Through Proper Integration and Tailoring Of Aero. Surfaces	Analytical Methods Available.	-None- For 1980 IOC	Upwards From 3% In L/D Increase

TABLE 2. PROPULSION ADVANCED TECHNOLOGY CONCEPTS

TECHNOLOGY CONCEPT	WHAT IT DOES	DEVELOPMENT STATUS	DEVELOPMENT COST & TIME	TECHNICAL PAYOFF POTENTIAL
Turbine Cooling Air Pre-Coolers	Uses Fan Air To Pre-Cool Engine Bleed For Turbine Rotor Cooling.	Studies Show Significant Gain For Current Engines; Smaller Gains For Advanced Technology Engines.	$20 M For 1985 IOC	For Current Engines, 6% SFC Gain. For Advanced Engines, Negligible SFC Gain.
Regeneration	Utilizes Rotary Heat Exchanger To Transfer Heat From Exhaust To Compressor Discharge Air. Improves SFC At Expense of Weight & Cost.	Studies Show Significant SFC Gain For Current Engines; For Advanced Technology Engines, Gains Are Minimal, And Do Not Justify Large Weight Increase.	Development Of A Regenerative Engine Will Be An Undertaking Of Major Magnitude. $200 M + For 1990 IOC	For Current Engines, 5 To 10% SFC Improvement with 30 To 70% Engine Weight Increase. For Advanced Engines, Negligible Improvement.
Advanced Component Aerodynamics	Component Aerodynamic Development And Improved Mechanical Design Techniques Offer Significant SFC And Weight Improvements	Studies Show That Fan Loadings And Efficiencies Will Increase By 20% & 3% Respectively; Compressor Tip Speeds & Efficiencies By 10% & 1 To 2%; Turbine Loading & Efficiencies By 20% & 1%	Major Development Program And Expenditure Required. $100 M For 1990 IOC.	7 to 10% SFC Gain With Small Weight Reduction. Reduced Engine Cost Reduced Maintenance Costs.
Advanced Materials, Cooling Effectiveness & Combustor Pattern Factors.	Use of Directionally Solidified Eutectic Alloys, Better Cooling & Improved Pattern Factors Reduce Turbine Cooling Air Reqts.	Studies Show A Potential Increase of 300°F Over Current Combustor Exit Temperatures	Development Program Req'd. $80 M For 1990 IOC.	6-8% SFC Gain Over Current Engines With Little Weight Penalty.
Electronic Control System.	Replaces Current Mechanical Cable & Hydro-Mechanical Engine Control System.	Studies Show Potential Gains In System Weight, SFC, Engine Response & Hot Section Life. Full-Scale JT8D Engine Tests With Electronic Control Successfully Compl.	Technology Available-- System Could Be Available Within 4 Yrs. $5M + For 1985 IOC	1 To 2% SFC Gain With Significant Reduction In Maintenance Costs.
Engine & Nacelle Structural Integration (PANSIP)	Improves Engine Durability and Performance By Properly Accounting For Airframe Induced Loads, & Minimizes Installed Weight.	Joint Boeing/GE/PWA Study Initiated 1974 Shows That SFC Deterioration And Maintenance Costs Can Be Minimized By Better Definition Of Loads.	Basic Technology Is Available-- Additional Testing & Development Req'd. For Application To New System; $10 M For 1985 IOC.	1 To 2% Improvement In SFC, Maintenance Costs.

TABLE 2. PROPULSION ADVANCED TECHNOLOGY CONCEPTS (CONT'D)

TECHNOLOGY CONCEPT	WHAT IT DOES	DEVELOPMENT STATUS	DEVELOPMENT COSTS & TIME	TECHNICAL PAYOFF POTENTIAL
Improved Nacelle Aerodynamics.	Optimizes Thrust-Minus-Drag Of Nacelle Installation By Aerodynamic Tailoring Of Internal & External Nacelle Lines.	Additional Development Of Existing 3D & Boundary Layer Programs Required To Provide Necessary Design Tools.	Minimal \$ For 1985 IOC.	1% Reduction In Installed SFC. Plus Reduced Development Costs.
Advanced Fans & Prop-Fans.	Utilizes Very High By-Pass Ratio (10 To 50), Low Press. Ratio (1.05 - 1.4) Turbo-Fans To Achieve High Pro-pulsive Efficiency i.e. Low TSFC.	Studies Show Signif-icant Reduction In SFC. Major Tech. Concerns Exist, i.e. Safety (Blade Failure), Mainten. Cost, Reliability, And Fan Efficiency At Cruise Speeds Above M=0.75-0.80.	\$100 to 200 M For 1990 IOC.	Up To 25% Reduction In SFC At Expense Of Increase In Engine Wt. (Uninstalled) & Increased Maint. Costs & Reduced Cruise Speeds

TABLE 3. STRUCTURES ADVANCED TECHNOLOGY CONCEPTS

TECHNOLOGY CONCEPT	WHAT IT DOES	DEVELOPMENT STATUS	DEVELOPMENT COST & TIME	TECHNICAL PAYOFF POTENTIAL
ACTIVE CONTROLS				
Augmented Stability	Reduced Size Of Empennage & Wing	Has Been Flight Tested On F-16	$8 Million 1985 Production Status	-1.5% OEW
Gust Load Control	Reduced Wing Bending Moments	Theoretical Analysis Complete - Experimental Flight Tests On Military Aircraft		-1% OEW
Maneuver Load Control	Reduced Wing Bending Moments			-4% Wing Box
Fatigue Rate Reduction	Reduction In Wing Bending In Turbulence			-3% Wing Box These May Not Be Additive
Flutter Mode Control	Elimination Of Stiffness Critical Structure			Configuration Dependent
MATERIALS				
Improved Aluminum Alloys	Increases In Strength, Fatigue Life, And Toughness	In Work 1975-1979	$1.5 Million 1979 Production Status	5% Weight Reduction In Strength Critical Areas
Cast Primary Structure	Reduced Cost	In Work 1976-1979	$2.5 Million	30% Cost Reduction
Improved Steel & Titanium Alloys	Increases In Stress Corrosion Resistance Of 230 KSI Steel	High Temperature Titanium Alloys In Development	$80 M 1985	40% Weight Reduction In High Temp. Ftgs.
Composite Primary Structure	Increases In Strength And Stiffness	Small Components In Service	$150-$300 M 1990	15% to 25% Weight Reduction
Aluminum Powder Metallurgy	Increase In Strength, Toughness, Fatigue Life Of Plate, Die Forgings and Extrusions	Small Extrusions Produced. Major Mill Facilities Req'd.	$2-$4 M + New Mills 1990	8% To 10% Weight Reduction
MANUFACTURING				
Improved Fabrication Processes	Reduced Detail Cost	1978 - 1979		Cost Reduction
Improved Assembly Techniques	Reduced Assembly Cost And Improved Quality	1978 - 1979		
Computer Aided Manufacturing	Improved Parts Control, Reduced Inventory Cost, Lower Manufacturing Cost	1982 Production Status	$6 Million	
Improved Inspection Methods	Reduced Life Cycle Cost	In Work	$2 Million	

TABLE 4. MECHANICAL/ELECTIRCAL SYSTEMS ADVANCED TECHNICAL CONCEPTS

TECHNOLOGY CONCEPT	WHAT IT DOES	DEVELOPMENT STATUS	DEVELOP COST & TIME	TECHNICAL PAYOFF POTENTIAL
SECONDARY POWER & CONTROL SYST. MECH. LOX-JP4 APU	Provides Substantial Weight Reduction	USAF Funded Prog. To Dev. Gas Gen. & Other Equipment - Low Risk	$.5 M - $1 M For 1980-85 IOC	ΔWT = 100-500 lb
Adv. Integrated Actuators	Reduces Hyd. Syst. Wt. - Improves Actuated Syst. Suev. - Reduces Flt. Control. Surf. Wt.	Prototype Hdwre. Partially Devel. - Medium Risk	$1 M - $2 M For 1980-85 IOC	ΔWT = 700-1500 lb
Actuation Control Signal Transducers (Digital, Fiber Opt.)	Improves Flt. Control Reliability & Airplane Surv.	In Development - Low Risk	$1 M 1980-85 IOC	ΔWT = 150 lb
Lt. Weight High Press (8000 PSI) Hyd. Syst.	Reduces Hyd. Syst. And Actuator Weights	Limited Devel. Currently - Med. Risk	$2 M 1980-85 IOC	-30% Syst. Wt.
VSCF Permanent Starter/Generator	Combines Starter & Gen. Into One - Reduces Wt., Improve Power Gen. Eff.	Presently Being Dev. By G.E. Under USAF Contract	$2 M - $5 M For 1980-85 IOC	ΔWT~150 lbs
ECS-AVIONICS COOLING SYSTEM Adv. Cooling Cycles - Closed Loop, Turbo-Ram Air, Positive Disp. Mach, Recirc.	Reduced Bleed, Ramair, Rqmts. - Fuel Heat Sink	New Concepts Show Signif. Reduction In Operating Penalty - USAF/FDL Has Current Test Prog. To Assess Positive Disp. Machines & Adv. ECS Cooling Pacs.	$1 M For 1980 IOC	2-4% SFC

TABLE 4. MECHANICAL/ELECTRICAL SYSTEMS ADVANCED TECHNICAL CONCEPTS (CONT'D)

TECHNOLOGY CONCEPT	WHAT IT DOES	DEVELOPMENT STATUS	DEVELOPMENT COST & TIME	TECHNICAL PAYOFF POTENTIAL
LANDING GEAR-BRAKES SYSTEM Limited Sup - Closed Loop Anti-Skid Syst.	Reduces Tire Skidding	Breadb'd Phase Of Dev. - Eval. On Brake Control Analog - Hardware Simulator	$.5 M For 1980-85 IOC	10% Improved Field Length Perf. + 10% Reduction In Tire Maint. Costs.
Active Lndg. Gear (Shock Strut)	Reduced Airframe Struc. Load & Wt. + Wider Operational Capability	Studied On USAF Contract For YC-14	$1 M For 1980-85 IOC	100-200 Lb. Wt. Reduction + Wider Operating Range
Active Steering/Gnd. Handling	Provide Better Aircraft Control	Study Status - No Hardware	$2 M For 1980-85 IOC	Reduce Maint. And Repair Costs Due To Veeroffs
Air-Cushion Lndg. System	Operation From Un-improved Fields-Reduced Structural Loads Better Floatation.	Currently Being Eval. On Jindivik And Buffalo in Flying Hardware. Eval. Needs Ext. To Larger A/P's	$2 M - $5 M For 1985 IOC	Reduced Wt., Runway Cost Savings.
Adv. Carbon Brakes	Reduce Brake Wt. To Less Than 2/3 That Of Steel Brakes	Currently In Operational Use - Contamination Problems & High Operating Costs	$2 M - $5 M For 1985 IOC	Reduced Brake Wt. By 1/3 (~2000 Lbs.)

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APPENDIX F

BASELINE MISSION SENSITIVITY BLOCK FUEL AND BLOCK TIME

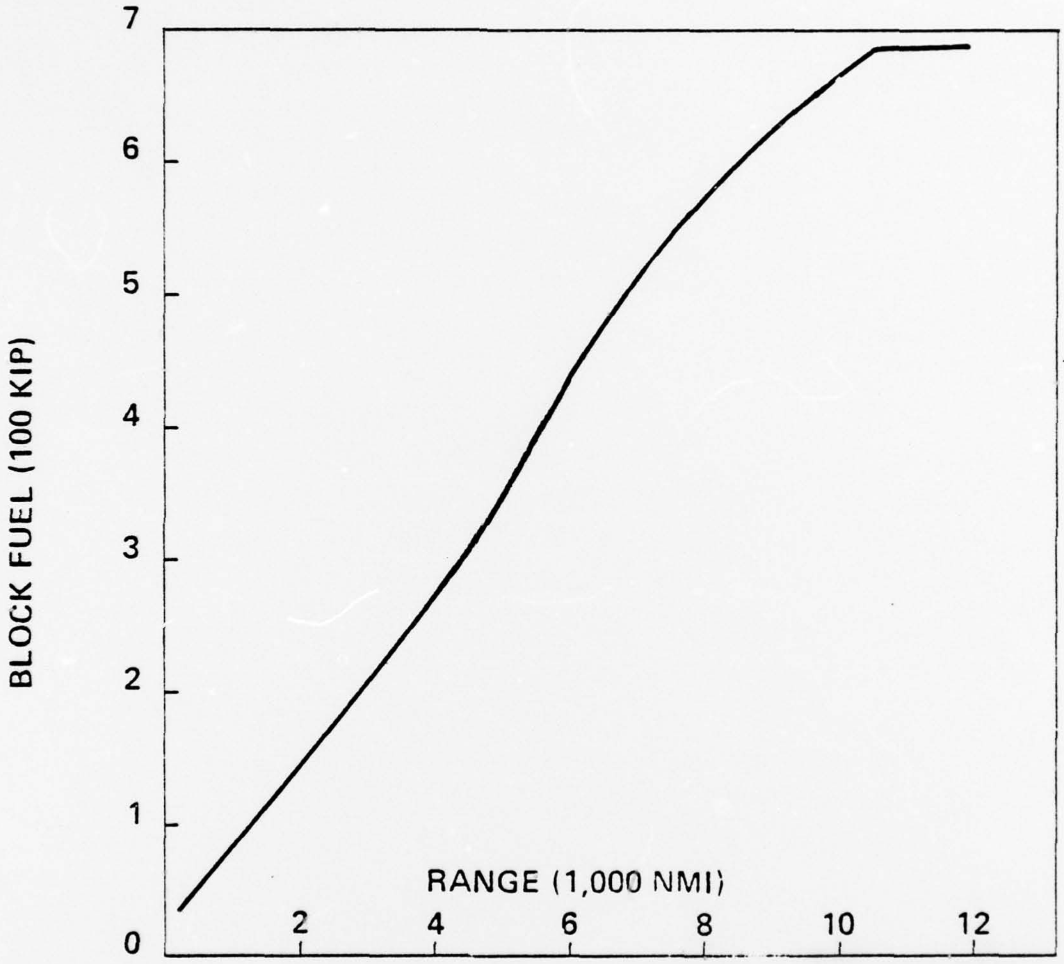

Figure 1. Block Fuel

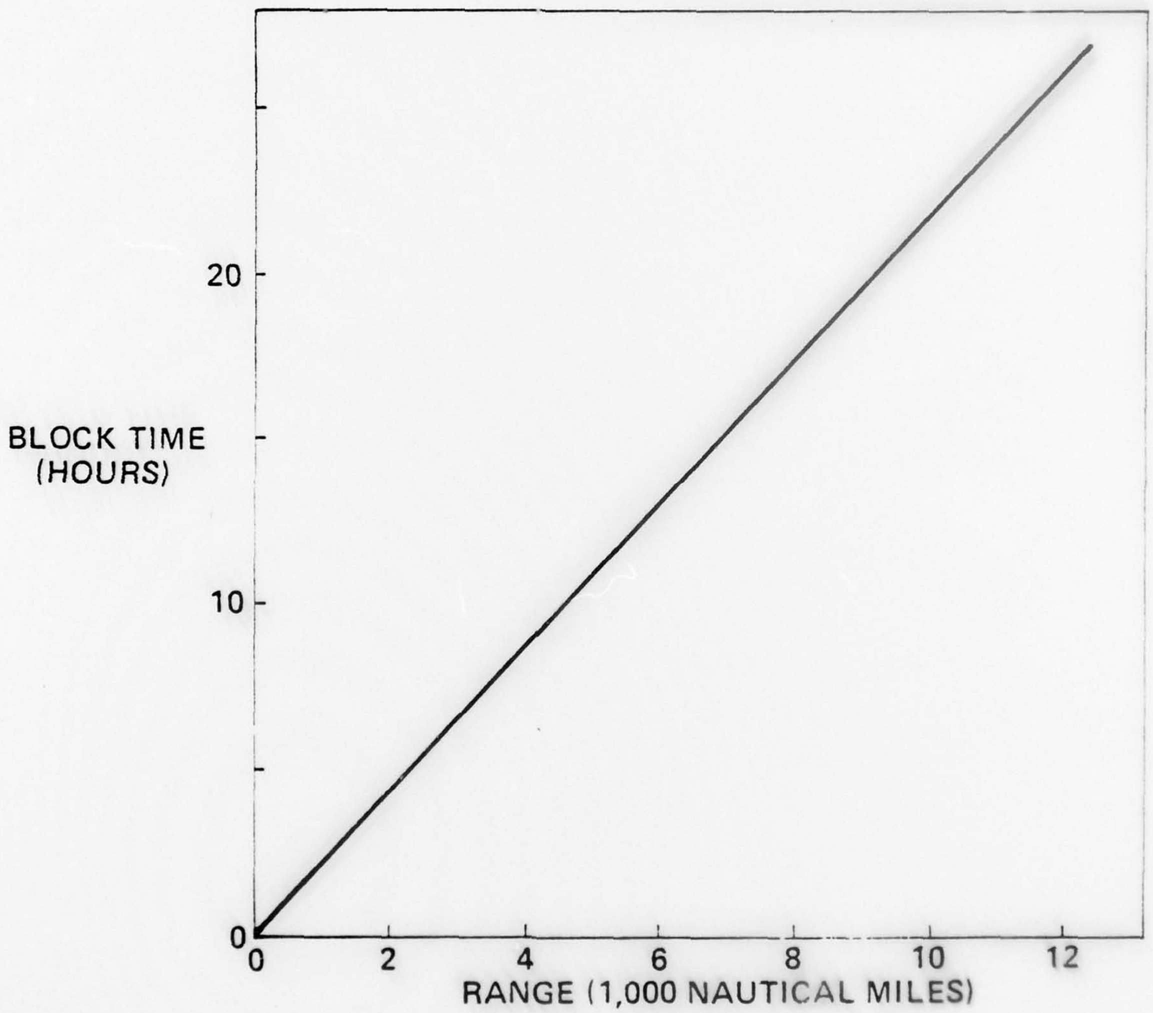

Figure 2. Block Time

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APPENDIX G

WEIGHTS METHODOLOGY

APPENDIX G

WEIGHTS METHODOLOGY

1.0 WEIGHT ANALYSIS

1.1 Prediction Methods

Parametric and point design weights for this study were estimated from modified parametric/statistical methods published in the Boeing document, D6-15095 TN Rev F, "Guidelines for Mass Properties Estimating." The accuracy of the D6-15095-TN methods to predict weight for 45 actual aircraft is shown in Fig.1. Weight prediction techniques for the I.A.D.S. type of airplane were computerized for parametric studies and integrated into the performance design synthesis program so that the fallout airplanes could be mission sized. Figure 2 is a weight summary of the validated model 1044-013 configuration.

Weight increments for the double arc body shape, wing struts and cryogenic fuel containment were developed fromdetailed analysis side studies. Parametric weight equations to cover these special features were developed, computerized and used appropriately.

2.0 Advanced Technology Weight Reduction

The fluence of advanced technology (1985 time period) was applied by factoring current technology group weights in the following manner:

Group	Factor Applied to Current Technology Weight
Wing	.895
Horizontal tail	.895
Vertical tail	.895
Body	.963
Main landing gear	.967
Surface controls	.781
Hydraulics system	.700

These factors were developed from consideration of specific advanced technology that was considered applicable for this design time period due to current industry research activities in the following areas:

1) Active controls
2) Advanced materials
3) Advanced structural arrangements
4) Improved analysis and design methods
5) Integrated control surface actuators
6) High pressure hydraulics system

3.0 Trade Studies

Special body weight trade studies were conducted in order to determine weight trends for varying outside contour of the lower radius, design differential pressure and number of cargo pallet lanes. Preliminary stress sizing calculations were used to establish these weight trends. Figure 2 depicts the method developed for computing weight increments for a double arc cross section with varying lengths of lower arc radii. The results of the pressure differential and number of cargo lanes studies were compared to the values developed by the basic fuselage weight prediction method in order to make certain that the weight trends for these issued (developed in the parametric studies) are practical. As a result of these studies, it was decided that the current Level I estimating methods for fuselage weight prediction were adequate, but that a research program should be established to design in detail and calculate weights of a fuselage for a large military cargo transport airplane with a double arc body cross section. This study would be conducted after the final cross section shape and payload were established.

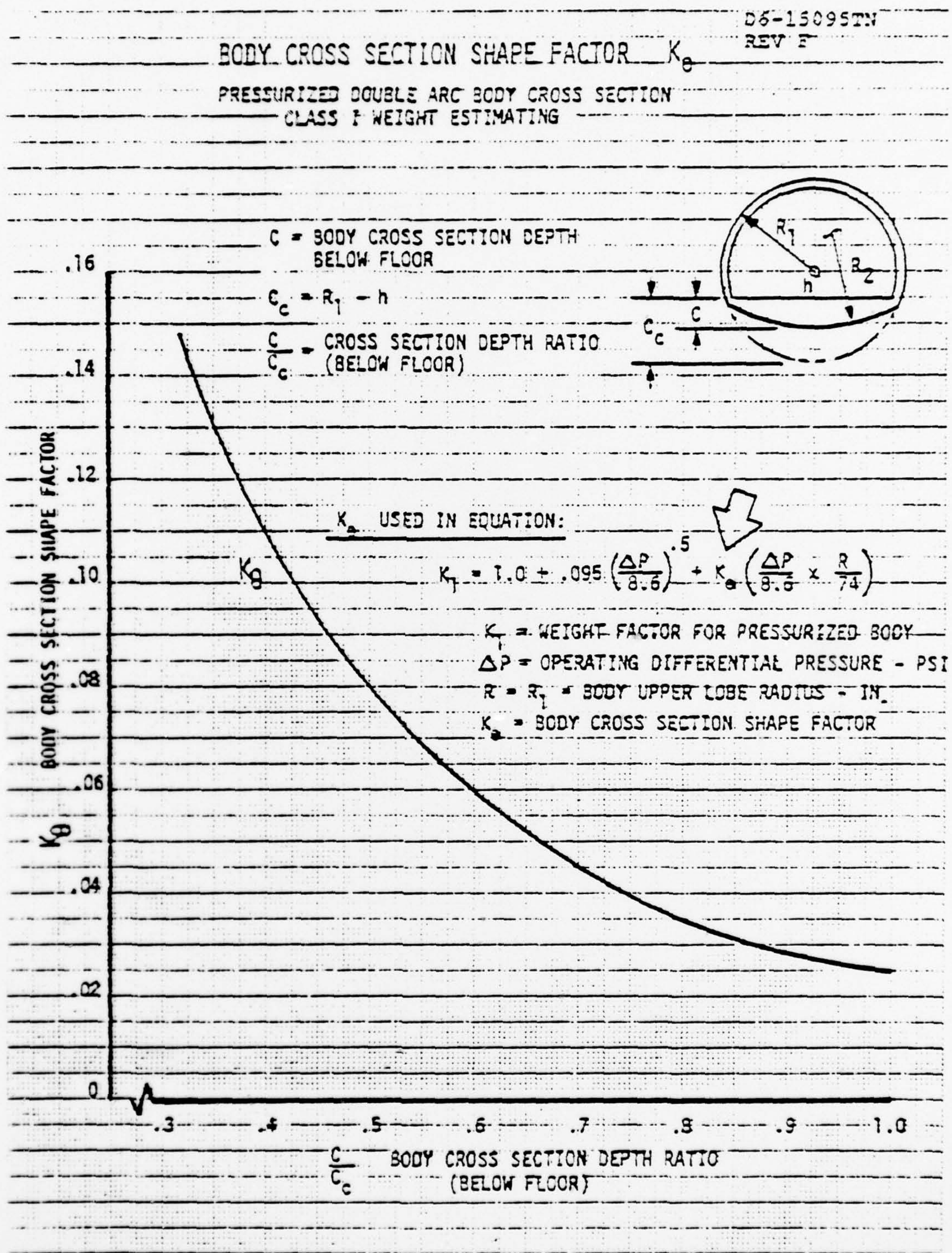

Figure 1. Body Cross Section Weight

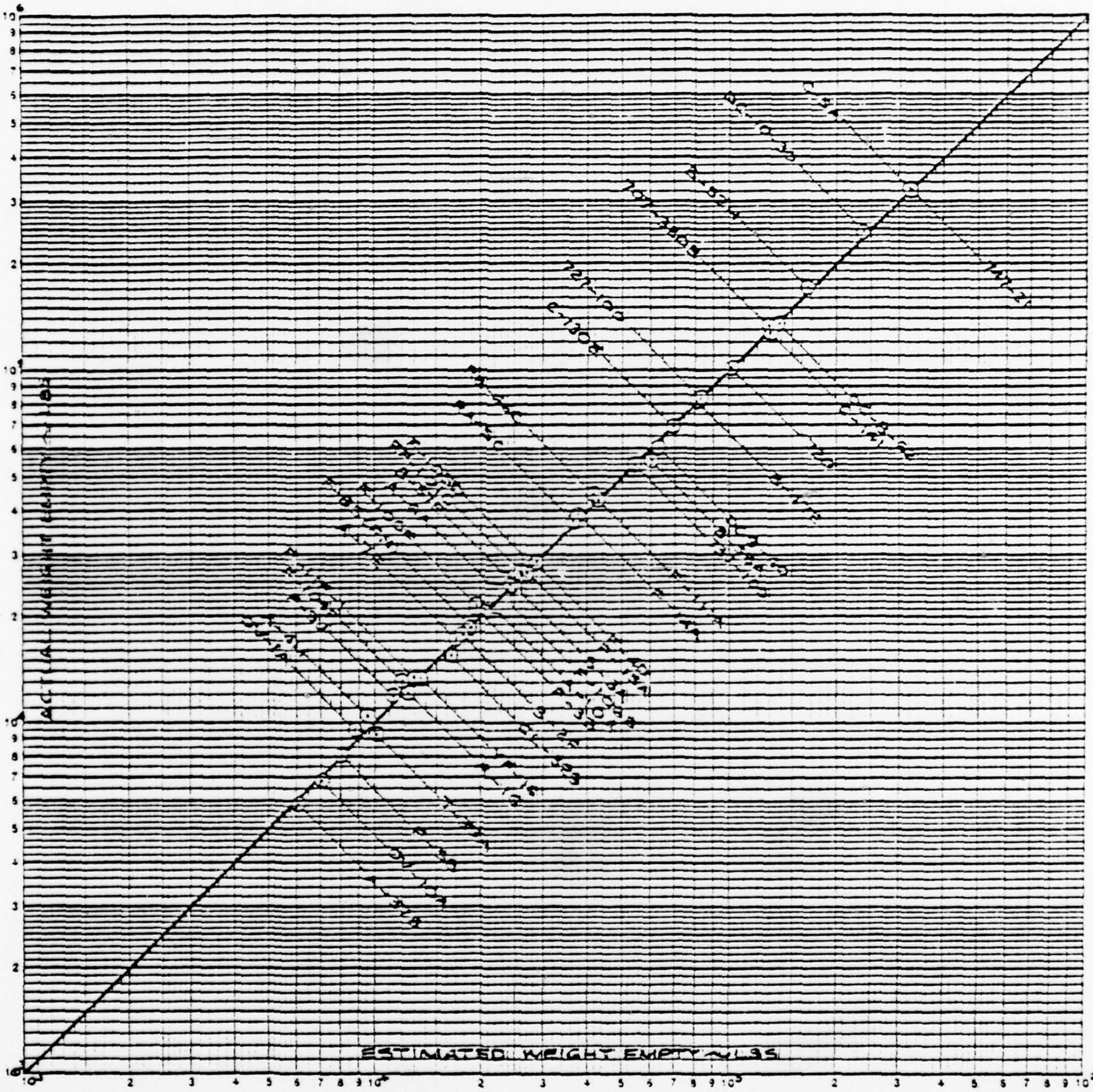

Figure 2. Weight Empty Correlation

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APPENDIX H

ADVANCED TECHNOLOGY COST FACTOR METHODOLOGY

1.0 TECHNOLOGICAL COST GROWTH INDEX

The 1985 technology airplane was priced using the current technology airplane price as a base and factoring it for technological growth. The factor used was +10%.

This factor was derived from an analysis that placed the price to the government of a current technology fighter (F-15) about 25% higher than prior generation fighters. The earlier fighters were represented by the present Rand airplane cost model.

Transport type aircraft do not progress as quickly as fighters in a technological sense. Our analysis indicates that transport aircraft may only advance at 40% of fighters. As a result a +10% factor was applied for pricing the 1985 technology airplane.

2.0 COMPOSITE STRUCTURE COST FACTORS

The composite airplane was priced based on the latest Boeing experience in both the production and development shops. Cost elements were individually analyzed to arrive at the following adjustment:

	Cost Adjustment to the Basic Aluminum Airplane
Engineering	+30% (hrs)
Tooling	+20% (hrs)
Production Labor	+10% (hrs/lb composite structure)
Material	+250% (cost)

Combined with a weight reduction in MEW from 581,000 to 536,000 pounds, the above adjustments resulted in a net price increase of +20% for the composite airplane.